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SEASONAL CHANGE AND PRODUCTION IN A MESIC PRAIRIE RELICT IN KALAMAZOO COUNTY, MICHIGAN

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Scientific interest in native grassland has increased in the past few years (e.g., Stuckey & Reese 1981, Brewer 1983). Information other than species lists is rare for Michigan grassland and especially meager for mesic prairie. Presented here are studies of seasonal change and production on a small relict of Genesee Prairie, a mesic prairie in southwestern Michigan. I was especially interested in examining Weaver's (1944) generalization that flowering is progressively higher as the season advances. Pokora (1968) previously studied seasonal change in a Van Buren County sand prairie and Brewer (1965) presented a small amount of information on phenology and standing crop in a Kalamazoo County wet prairie.

STUDY AREA

The remnant was on an old railroad right-of-way east of Oshtemo at the northern border of the original prairie (Brewer 1984). The study area was divided into three sites: ridgetop, which may have represented original prairie soil; roadbed, abandoned in the late 1920s and located in a cut about 6 m deep; and the steep (37°) slope between the other two sites.

About a hundred plant species were identified on the study area. Big bluestem (*Andropogon gerardii*) was the dominant grass on all sites.

METHODS

Phenological observations were recorded on many visits between September 1961 and April 1970; however, a special effort was made to study seasonal change in 1963. On 17 visits between 23 March and 7 November, I traversed the area to note stage of development (initiation of growth, buds, flowers, fruits, dispersal) and measure heights (with a meter stick) for the important species. On every visit I tried to follow the fortunes of several characteristic species (Table 1). Opportunistic observations were also made on many others. A typical visit included data on 150–200 stems of 35–40 species. Except where otherwise indicated, observations on phenology are for the slope and ridgetop combined, with the drier roadbed omitted.

In classifying species as native or introduced, I used Gleason and Cronquist (1963); in classifying them as prairie (including oak openings) or non-prairie, I used Curtis (1959: 633–644).

Standing crop and productivity were studied using clip quadrats taken at approximately monthly intervals from late May to November 1963 and also in April 1964. On each date 20 0.5-m² quadrats were taken, 5 in each of 4 randomly selected lines running from roadbed to ridgetop. All living above-ground herbaceous vegetation plus any dead material from the current growing season was placed in paper bags. In the laboratory, the vegetation was stored at –20° C until it could be sorted to species, oven-dried at 110° C, and weighed to the nearest 0.01 g.

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GRIFFIN

Annual net primary production for the herbs was determined by the short-term crop method (Odum 1960). For species of at least 25% frequency (Brewer 1984: Table 1) on each site, peak seasonal biomass was taken as the estimate of net production. For rare species, which might be over- or under-represented in a given monthly sample, I summed all the weights for the period during which peak biomass might have occurred and divided by the number of samples. Since this included one or more time periods before or after peak biomass, it tended to underestimate production for those species. Production per m^2 was obtained by summing the values for the individual species.

I measured dominance by computing how many species were required to contribute 90% of the production on each site (by summing production figures by species in descending order of magnitude until the summation reached or exceeded 90% of the total for the site).

Woody plant production was sampled only once, in September 1963, for the middle of the slope. In 6 randomly selected m^2 quadrats, above-ground parts of woody plants were processed like the herbaceous vegetation. Separate weights were obtained for leaves and stems. For stems, weights were divided by age of stem (annual rings or terminal bud scars) to obtain average annual production figures.

Influence of slope on effective sampling area. Quadrats taken on sloping ground sample less than their nominal size in horizontal space. For example, a m^2 quadrat taken on the slope here sampled 0.76 m^2 of horizontal area. Some vegetational features probably are more dependent on horizontal than on ground area. Productivity, which would be related to the leaf surface exposed to light, is one; accordingly, I multiplied the values obtained for standing crop and productivity for slope quadrats by 1.31 to express results per m^2 of horizontal area.

WEATHER

Both 1962 and 1963 were years of below-average rainfall for Kalamazoo (longterm mean = 34.27 inches; 1962 = 29.46, 1963 = 26.90; Strommen 1971). The deficit was about 5 inches in 1962 and more than 7 in 1963. Although January, February, and April 1963 had low precipitation, March had above-average and May, average amounts, so that at the beginning of June the year's deficit, compared with long-term figures, was only 1.59 inches. June was dry, receiving only 1.98 inches (compared with a long-term average of 3.76), that coming near the beginning of the month. Drought continued in early July but heavy rains in the last half of the month brought the figure above the long-term July average; August and September were wet and more than made up the deficit for the growing season as a whole. Below-normal rainfall characterized October–December.

Temperatures in 1963 were above-normal for March, October, and November and below-normal for February and August.

PHENOLOGY

Seasonal Development. The prairie was usually snow-covered at the beginning of the year. In years of heavy snow cover, the vegetation exposed by the spring melt was flattened, matted and, in some years, covered with mold. This was true in 1963 when snow cover was complete until mid-March. The general aspect of the prairie was brown and dead well into April, although by early March of some years new growth of several species was beginning.

Probably the earliest species to flower was tufted buttercup (*Ranunculus fascicularis*) and the latest, smooth aster (*Aster laevis*) (Fig. 1). The last

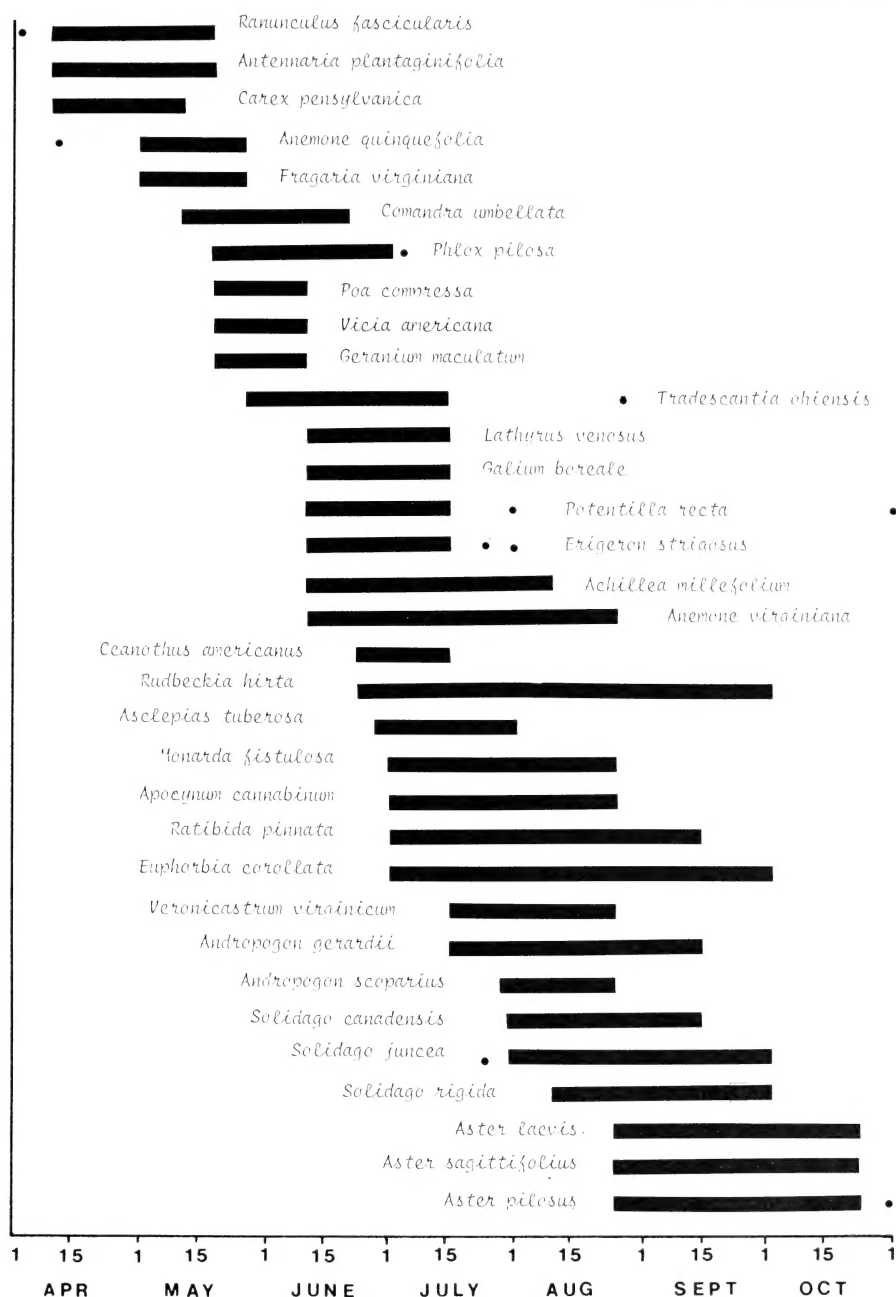


Fig. 1. Period of bloom of important species at Oshtemo Prairie. The continuous bars are the period of bloom in 1963. The period of bloom was taken as starting halfway between the last date with only buds and the first date of open flowers. The end of bloom was taken as halfway between the last date with open flowers and the next date of observation. Dots are dates outside the 1963 ranges when species were recorded in bloom in other years.

species to retain flowers were frost aster (*A. pilosus*) and sulphur cinquefoil (*Potentilla recta*), which still had a few blossoms on 1 November 1964. The number of species in flower built up slowly from April to June and then jumped. July was the peak of bloom but August and early September remained high (Fig. 1).

Most of the plants that had sprouted by 24 April were between 5 to 10 cm tall (Table 1) but the dominant cover at this time was still litter from the previous year. Median height of big bluestem was a good measure of general vegetation height. It rose from about 12 cm on 7 May to 136 on 4 August, the first date I observed big bluestem in flower (Fig. 2). Peak height, about 150 cm, occurred in September. Later-flowering species tended to be taller than earlier-flowering ones until August but not afterwards (Fig. 1).

Wintergreenness. Few wintergreen species occurred. On three visits in January and February, only a handful of species had any green foliage (Table 2). Several species with green basal foliage in November nearly or completely winter-killed. Included were goldenrods (*Solidago rigida* and others), asters (*Aster* spp.), downy phlox (*Phlox pilosa*), black-eyed susan (*Rudbeckia hirta*), Queen Anne's lace (*Daucus carota*), and strawberry (*Fragaria virginiana*). Vetchling (*Lathyrus venosa*) after dying back in late September, sometimes re-sprouted but also winter-killed.

DROUGHT EFFECTS

The slow growth, or even loss of height, shown (Fig. 2) in late June-early July for big bluestem was real, the result of a prolonged dry spell. Between 11 June and 13 July only 0.38 inch of rain was recorded at the Kalamazoo weather station. The effects were most evident on the driest site, the roadbed. On 5 July, wilting was widespread on the roadbed and by 8 July many plants there had dead leaves. On this date, wilting of the more susceptible species, such as coneflower (*Ratibida pinnata*), had become noticeable on the ridgetop. The following species were noted as obviously affected (dead leaves) by the drought: big bluestem, little bluestem (variable; not as bad as *A. gerardii*), white sweet clover (*Melilotus alba*), wild bergamot (*Monarda fistulosa*) (variable), Canada bluegrass (*Poa compressa*), coneflower, bouncing bet (*Saponaria officinalis*), rigid goldenrod (*Solidago rigida*) (not as bad as *R. pinnata*).

The following species were recorded as showing no wilting or dead leaves: dogbane (*Apocynum cannabinum*), butterfly weed (*Asclepias tuberosa*), flowering spurge, tall cinquefoil (*Potentilla arguta*), bracken (*Pteridium aquilinum*), rose (*Rosa carolina*), and meadow goat's beard (*Tragopogon dubius*).

On 24 July, ten days after the drought was broken, flowering stalks of big bluestem had begun to shoot up on ridgetop and slope, raising the median height ($n=21$) to 110 cm. No flowering stalks were yet evident on the roadbed; median height ($n=6$) was only 57 cm. The eventual height on the roadbed (6 and 23 September combined, $n=11$) was 155 cm, indistinguishable from the other sites (Fig. 2).

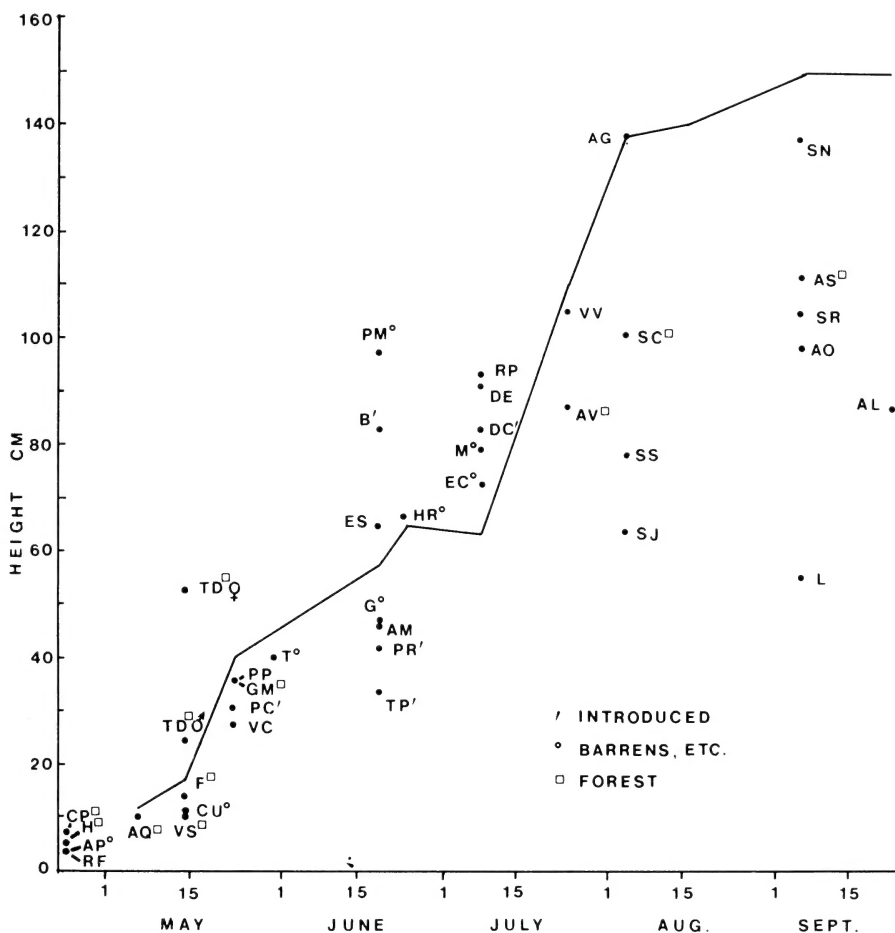


Fig. 2. Relationship between overall vegetation height and date of flowering at Oshtemo Prairie. The solid line is the median height of big bluestem (AG), used as an indicator of overall vegetation height. Dots are median heights of each species for the date it was first found in flower. Key to other abbreviations: AL, *Aster laevis*; AM, *Achillea millefolium*; AO, *Aster pilosus*; AP, *Antennaria plantaginifolia*; AQ, *Anemone quinquefolia*; AS, *Aster sagittifolius*; AV, *Anemone virginiana*; B, *Bromus inermis*; CP, *Carex pensylvanica*; CU, *Comandra umbellata*; DC, *Daucus carota*; DE, *Desmodium canadense*; EC, *Euphorbia corollata*; ES, *Erigeron strigosus*; F, *Fragaria virginiana*; G, *Galium boreale*; GM, *Geranium maculatum*; H, *Hepatica americana*; HR, *Heuchera richardsonii*; L, *Liatris novae-angliae*; M, *Monarda fistulosa*; PC, *Poa compressa*; PM, *Polygonatum commutatum*; PP, *Phlox pilosa*; PR, *Potentilla recta*; RF, *Ranunculus fascicularis*; RP, *Ratibida pinnata*; SC, *Solidago canadensis*; SJ, *Solidago juncea*; SN, *Sorghastrum nutans*; SR, *Solidago rigida*; SS, *Andropogon scoparius*; T, *Tradescantia ohiensis*; TD, *Thalictrum dioicum*; TP, *Trifolium pratense*; VC, *Vicia americana*; VS, *Viola sororia*; VV, *Veronicastrum virginicum*. Species without superscripts are modal in prairie and oak openings (Curtis 1959).

TABLE 1. Median height by date of various species at Oshtemo Prairie.

Species	Height (cm)					
	24 April	14 May	19 June	24 July	15 August	6 September
<i>Ranunculus fascicularis</i> ¹	5*	10.7	— ^a	—	—	—
<i>Carex pensylvanica</i>	5	17	—	—	—	—
<i>Antennaria plantaginifolia</i>	3	14	23	b	b	b
<i>Comandra umbellata</i>	7	11	23	35	—	28
<i>Phlox pilosa</i>	7	23	36	—	—	—
<i>Achillea millefolium</i>	6	10	43	55.5	—	—
<i>Galium boreale</i>	—	18	46.5	54.5	48	49
<i>Euphorbia corollata</i>	—	—	58	82	79.5	85
<i>Monarda fistulosa</i>	6	17	33	81	66.5	90
<i>Ratibida pinnata</i>	5	12	56.5	105	92	88
<i>Veronicastrum virginicum</i>	—	—	49	105	115	93
<i>Andropogon gerardii</i>	—	17	57.5	110	140	150
<i>Solidago rigida</i>	—	16.5	48.5	70.5	101	92
<i>Aster sagittifolius</i>	—	17	73	105	101.5	110
<i>A. laevis</i>	5.5	—	54	69	94	106.5

¹Roadbed

*Boldface signifies at or past flowering (anthesis)

^aDash signifies not observed^bPresent as rosettes

TABLE 2. Species at Genesee Prairie with some wintergreen foliage.

<i>Achillea millefolium</i> —prairie	<i>Potentilla recta</i> —introduced
<i>Antennaria plantaginifolia</i> —sand barrens	<i>Poa compressa</i> *—introduced
<i>Erigeron strigosus</i> —prairie	<i>Ratibida pinnata</i> **—prairie
<i>Hepatica americana</i> —boreal forest	<i>Saponaria officinalis</i> —introduced
<i>Hypericum perforatum</i> —introduced	<i>Trifolium pratense</i> —introduced

*Mostly around harvester ant mounds

**Occasional plants

STANDING CROP AND PRODUCTIVITY

Above-ground net production was highest on the ridgetop and lowest on the roadbed (Table 3). Big bluestem made the greatest contribution on all sites, ranging from about a third on the ridgetop to half on the roadbed.

Table 3 includes all species on each site that contributed at least 10 g of new organic matter. Owing to great point-to-point variability, the reliability of production and standing-crop estimates is low (Table 4). There were, nevertheless, obvious differences in the contributions of different species on different sites. For a given species, most differences in production were similar to, but of greater magnitude than, between-site differences in frequency (cf. Brewer 1984: Tables 2, 3). A few species with moderate or high frequencies contributed little biomass; examples are *Tradescantia ohimensis*, *Apocynum cannabinum*, *Melilotus alba*, and *Daucus carota*. The last two were usually found as small depauperate plants.

TABLE 3. Above-ground net production (g oven-dry weight/m²) for one growing season, Oshtemo Prairie.

Species	Site		
	Roadbed	Slope	Ridgetop
<i>Andropogon gerardii</i>	160.5	162.9	197.4
<i>Aster sagittifolius</i>	0	18.7	5.1
<i>A. scoparius</i>	17.1	13.0	5.5
<i>Antennaria plantaginifolia</i>	0	20.1	3.0
<i>Bromus inermis</i>	0	5.4	136.0
<i>Carex pensylvanica</i>	0	9.1	28.4
<i>Euphorbia corollata</i>	14.9	10.0	6.4
<i>Galium boreale</i>	0	20.6	2.3
<i>Lathyrus venosus</i>	0	3.9	20.0
<i>Monarda fistulosa</i>	3.6	15.9	0
<i>Potentilla recta</i>	44.6	0	0
<i>Poa compressa</i>	44.6	8.7	13.1
<i>Pteridium aquilinum</i>	1.2	21.2	11.2
<i>Ratibida pinnata</i>	25.9	1.1	6.3
<i>Solidago juncea</i>	0	2.0	87.2
<i>S. rigida</i>	0	0.2	15.5
Other species	19.4	71.4	49.7
Total	331.8	385.2	587.1

TABLE 4. Standing crop (g oven-dry weight/m²) of herbaceous vegetation on three sites at Oshtemo Prairie by month.

Month ¹	Site		
	Roadbed	Slope ²	Ridgetop
April	5.7	26.1 ± 15.20	no data
May-June	48.3	136.1 ± 35.95	133.6
July	161.4	266.2 ± 35.18	310.8
Aug.	176.9	274.0 ± 24.82	347.0
Sept.	235.8	290.2 ± 27.37	399.9
Oct.-Nov.	216.7	281.8 ± 39.14	382.4

¹1963, except April 1964²Mean ± standard error

Production as a percentage of peak biomass (Table 4) varied from 132% (roadbed) to 147% (ridgetop). Peak biomass came in September on all sites.

Among plants, dominance and diversity tend to be inversely related (Whittaker 1975: 96). Heavy dominance by a few species implies a monopolization of resources that tends to limit the occurrence of other species. The measure of dominance I used was the number of species required to contribute 90% of the total production on a site. Eighteen species were required on the slope, 11 on the ridgetop, and only 6 on the roadbed. This implies lowest diversity on the roadbed and highest on the slope, a result in accord with the trend suggested by species numbers (Brewer 1984).

The single determination of woody plant production was about 15 g/m² (Table 5) or about 4% of the herbaceous production (Table 3) on the same

TABLE 5. Woody plant production, middle slope (g oven-dry weight/m²).

Species	Stems	Leaves
<i>Ceanothus americanus</i>	1.31	0.47
<i>Corylus americana</i>	0.94	0.44
<i>Rhus glabra</i>	0.10	0.41
<i>Rosa carolina</i>	4.47	7.20
Totals	6.82	8.52
	15.34	

site. Yearly production in the form of leaves was slightly more than in the form of stems.

DISCUSSION

Weaver (1944) noted that flowering in prairie is near the top of the general vegetation level, rising through the course of the season. Pokora (1968) suggested that the species that deviated most from this seasonal progression were weeds. The implication is that native prairie plants form an integrated, evolved system.

Figure 2 examines graphically the seasonal relationship between general vegetation height and height at flowering of individual species. Through May the trend was for flowers to be borne close to, though below, the median height of big bluestem. At Oshtemo, as in the prairie Weaver (1954) described, early summer was a period in which a large proportion of the flowering species were taller than the general grass cover.

Past the end of July, the generalization of increasing flowering heights keeping pace with increasing grass height did not hold. The median height of species coming into flower in September was much the same as August and no species, except Indian grass (*Sorghastrum nutans*), was anywhere near the height of big bluestem. Prairies with species of *Silphium* or other tall composites might make better illustrations of Weaver's generalization; nevertheless, it is clear that several typical late-summer species bloom well below the general vegetation height.

My observations generally confirm Weaver's (1954) analysis of how the seasonal changes in vertical structure arise. Most species have begun growth by mid-April. On any one date, all species that have not yet flowered tend to be about the same height (Table 1). Growth in height usually ceases soon after flowering starts. The trend of increasing seasonal flower height results from plants engaged in food-making maintaining a position in the top level of the vegetation. Height of flowering, consequently, is determined by date of flowering, which is probably a compromise between many evolutionary pressures (Willson 1983: 161-165).

The foregoing implies that competition for sunlight is the prime evolu-

tionary determinant of the seasonal height progression. Successful plants in prairie, whether native prairie species or invaders from another community or another region, should be species that either (1) conform to the seasonal height progression (*conformers*) or else (2) circumvent the resulting light regime. Circumvention might be achieved in five conceivable ways: (a) growing taller than the general cover, (b) possessing a low compensation point, allowing growth in shade, (c) being wintergreen, (d) being parasitic, and (e) flowering late (rationale discussed below).

A plurality (7 of 15) of the native prairie species were conformers. Of species that did not conform, two, *Ratibida pinnata* and ticktrefoil (*Desmodium canadense*), were taller than the general grass cover when they flowered (Fig. 2). *R. pinnata* is also wintergreen (Table 2). No fewer than six species flowered well below the general vegetation level but did so late in the season. For many late-flowering plants, little would be gained by keeping pace with *Andropogon gerardii* flowering stalks because (1) plants have already had a long season to accumulate energy reserves and (2) the shade cast by bluestem flowering stalks is thin compared with that cast by its foliage.

A second group of species are those characteristic of a variety of open communities closely allied to prairie, such as barrens and fen. Six of eight species were conformers [of these, pussy-toes (*Antennaria plantaginifolia*) is also wintergreen and bastard toadflax (*Comandra umbellata*) is a root parasite]. The other species [bergamot and Solomon's seal (*Polygonatum commutatum*)] are tall. The absence of any species using the "late" strategy is noteworthy.

A third group of species are those characteristic of forest (or, one species, carr) but which also occur in prairies, especially wet-mesic prairie (Curtis 1959, Brewer 1984). Most of these are known or can be presumed to have low compensation points (Sparling 1967). Despite this, most (6 of 10) are conformers (one, *Hepatica americana*, is also wintergreen). One of the ten is tall, and two are late. The tenth species, *Anemone virginiana*, has no obvious adaptation other than its presumed good shade tolerance.

Introduced species form the fourth group. Supporting Pokora's (1964) postulate, only one of five conformed to the seasonal height progression [Canada bluegrass (*Poa compressa*) which is also wintergreen]. Two [smooth brome (*Bromus inermis*) and Queen Anne's lace] were taller than the general grass cover. Two were shorter but were wintergreen [*Potentilla recta* and red clover, (*Trifolium pratense*)].

As far as light is concerned, most of the benefits of tallness could be achieved by simply conforming to the seasonal height progression. It is possible that the advantages of tallness lie elsewhere, possibly in pollination. The early July period in which the species initiating flowering are above the general grass cover corresponds to the time when the greatest number of species are in bloom (Fig. 1). Possibly during this period competition for insect pollinators is important. For anemophilous species, tallness may be important for catching wind currents. This seems the most likely explanation

for the exaggerated height of meadow rue, which towers above the rest of the vegetation in mid-May. Wind pollination may also be a factor in the tallness of brome and Indian grass. Although the latter is below big bluestem, it is still far taller than any other September-blooming species.

Given the importance of wintergreenness in allowing introduced species to invade prairie, it seems paradoxical that so few native species are winter-green. Part of the explanation may be that for species able to stay in the gradually rising canopy, any additional advantage is slight. Also, winter conditions at ground level are severe in prairie. Insulation during the harshest part of the winter is poor because of slight (USDA 1941: 727) or variable (Brewer 1984) snow cover and porous litter (compared with forest). Finally, as we have already seen, several prairie species have green foliage late in the fall and probably are wintergreen in mild winters. They seemingly are just not as good at withstanding severe cold as a small number of alien species.

It seems certain that productivity was underestimated. Three biases, all in this direction, were involved. The first, based on the method used to calculate the contributions of rarer species, has already been mentioned. A second is the loss of plant material prior to peak biomass. This may be severe in some prairie species, for example, goldenrods with fugacious lower leaves. Also, no attempt was made to correct for animal consumption. Although most species showed little sign of grazing, a few such as New Jersey tea (*Ceanothus americanus*) showed obvious losses.

Even though the figures are underestimates, they are at the high end of the reported range for temperate grassland; for example, the highest above-ground net production reported by Sims and Singh (1978) on an ungrazed site was 416 gm/m² on a tallgrass prairie in Oklahoma.

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SUMMARY

A small remnant of Genesee Prairie, a mesic prairie in Kalamazoo County, Michigan, showed an expected pattern of taller species flowering later, until August. After that there was little increase in height of species coming into flower. The pattern is based on most species growing at about the same rate until they flower and then slowing or stopping growth. Competition for light is the most likely evolutionary explanation. Most invaders of prairie either conform to the seasonal height progression or circumvent the resulting light regime by being wintergreen. The latter strategy is prevalent in introduced species. Growing taller than the general grass cover, though it also provides access to light, may have improving pollination as its main function. Above-ground net production on different sites ranged from 332 to 587 oven-dry g/m². Peak standing crop (in September) ranged from 132–147% of estimated production. The calculated productivity figures were underestimates; nevertheless, they are among the higher values recorded for North American grassland.

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**PORTERANTHUS TRIFOLIATUS, BOWMAN'S ROOT,
VERIFIED IN THE MICHIGAN FLORA**

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Porteranthus trifolius (L.) Britt. or Bowman's Root, is a distinctive perennial herb of the Rosaceae. Its trifoliate, irregularly serrate leaves and white *Amelanchier*-like flowers give it the look of a tall, gangly *Geum canadense* (white avens) with overlong petals (Fig. 1). It is mostly restricted to rich mesophytic forest slopes of the upper piedmont and Allegheny-Appalachian mountain system. It is often placed with *P. stipulata* under the illegitimate generic name *Gillenia*. (Whether the name *Gillenia* Moench is an illegitimate homonym of *Gillena* Adanson and, if so, whether the latter should be conserved against *Porteranthus* Britt., are now being considered by nomenclatural committees, according to Voss.)

State floras suggest that the species has a mass range from New York and Pennsylvania south to Tennessee and South Carolina. Published native occurrences farther west—even from nearby areas—are few and disparate. Some reports date from the turn of the century; certain of these, lacking supporting voucher specimens, have been discounted by later floristicians. Others have been based on escapes from cultivation. Remaining are several reports of midwestern populations which are presumably native stands. A conservative picture of the midwestern distribution of indigenous *P. trifolius* will be presented elsewhere. Here I describe the site of an evidently native population I recently discovered in southwestern Michigan and evaluate previous reports of the species in the state.

In the Gourdneck State Game Area of Kalamazoo County, on 8 June 1979, I discovered a small colony of *P. trifolius* conspicuous in full anthesis. Plants were scattered through the ecotone between second-growth oak forest and shrub-carr surrounding a *Typha* marsh. Two dozen large and small plants grew in shade on sandy loam with a high silt component and pH of 5.3 (determined colorimetrically with a no. 693 Hellige-Truog Soil Reaction [pH] Tester). Among them were native species of forests and wetlands, listed in Table 1, that are common elsewhere in southern Michigan.

Potential garden sources of seed within a 2-mile radius of the Gourdneck population were sought without success. I have visited the site each year, and while I have noted gradual changes in the diversity and composition of the abutting plant communities and the ecotone where the species occurs, I have found the location and number of plants to remain essentially unchanged.

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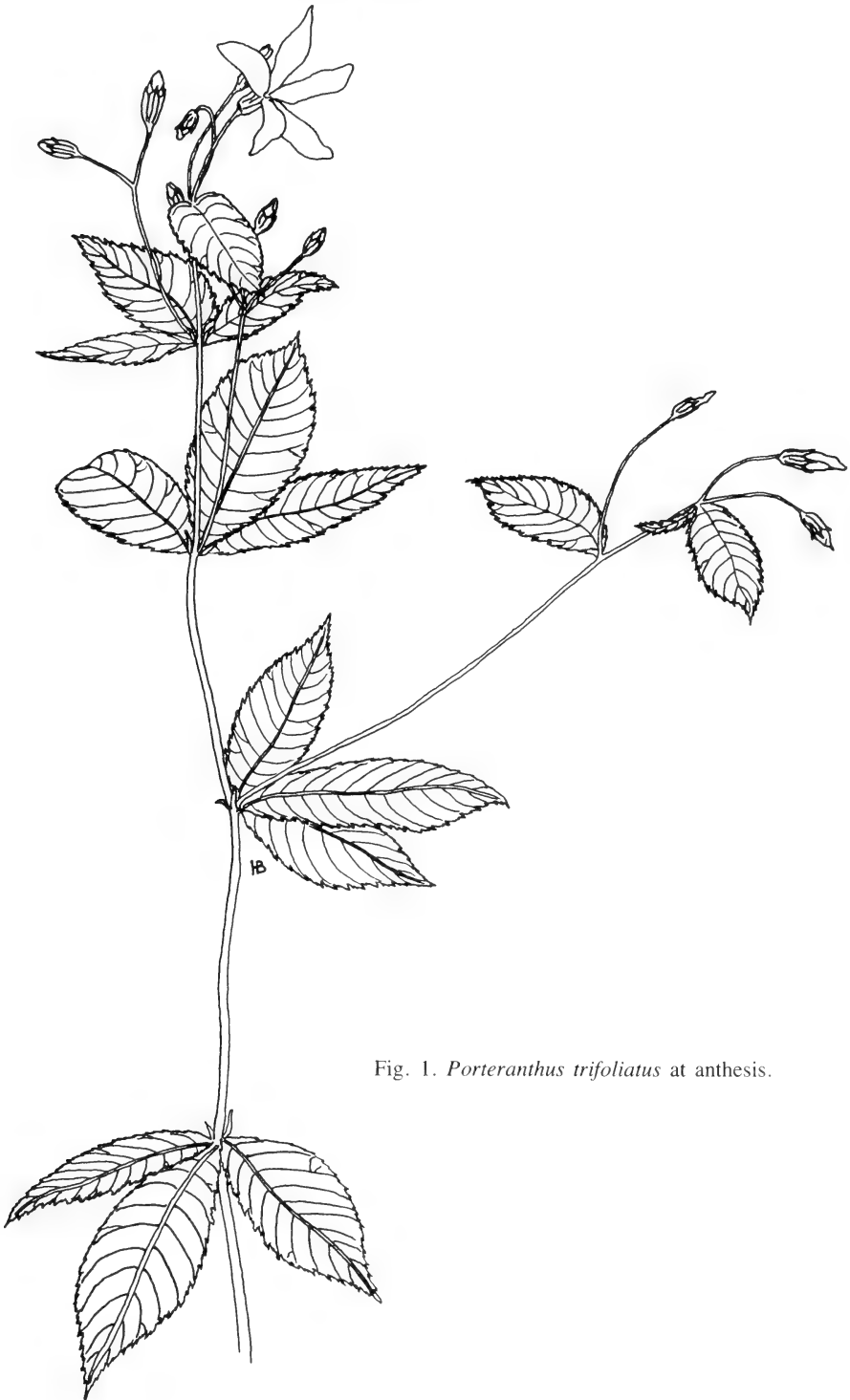


Fig. 1. *Porteranthus trifolius* at anthesis.

TABLE 1. Vascular plants at the Gourdneck *Porteranthus* site. Apparent dominants are denoted by an asterisk.

TREES	HERBS
<i>Acer rubrum</i>	<i>Agrimonia pubescens</i>
<i>Carya cordiformis</i>	<i>Anemone quinquefolia</i>
<i>Crataegus</i> sp.	<i>Anemonella thalictroides</i>
<i>Populus grandidentata</i>	<i>Apocynum androsaemifolium</i>
* <i>Prunus serotina</i>	<i>Carex pensylvanica</i>
<i>Quercus alba</i>	<i>C. swanii</i>
<i>Q. borealis</i>	<i>Coreopsis tripteris</i>
* <i>Q. palustris</i>	<i>Equisetum laevigatum</i>
* <i>Q. velutina</i>	<i>Galium aparine</i>
<i>Rhus glabra</i>	<i>G. boreale</i>
* <i>Sassafras albidum</i>	<i>Geum canadense</i>
	<i>Impatiens</i> sp.
SHRUBS AND VINES	<i>Krigia biflora</i>
<i>Amelanchier sanguinea</i>	<i>Lathyrus ochroleucus</i>
<i>Aronia</i> sp.	<i>Luzula multiflora</i>
<i>Ceanothus americanus</i>	<i>Lysimachia quadriflora</i>
<i>Cornus racemosa</i>	<i>Osmorhiza claytoni</i>
* <i>Gaylussacia baccata</i>	<i>Podophyllum peltatum</i>
<i>Parthenocissus quinquefolia</i>	<i>Polygonatum biflorum</i>
<i>Rhus radicans</i>	<i>Potentilla simplex</i>
<i>Rosa carolina</i>	* <i>Pteridium aquilinum</i>
<i>Rubus allegheniensis</i>	<i>Sisyrinchium albidum</i>
<i>R. pubescens</i>	<i>Smilacina racemosa</i>
<i>Smilax lasioneura</i>	<i>Stellaria longifolia</i>
<i>Spiraea alba</i>	* <i>Tradescantia ohimensis</i>
<i>Vaccinium vacillans</i>	<i>Triadenum fraseri</i>
<i>Viburnum acerifolium</i>	
<i>Vitis aestivalis</i>	

According to habitat descriptions in floras for the Appalachian states where *P. trifoliatum* is common, the Gourdneck site approximates native conditions for the species. Furthermore, the soil pH around *P. trifoliatum* at the Gourdneck site is near the value (pH 6.0–8.0) said to be preferred by the species (LaMotte Chemical Products Company, 1978). Circumstantial evidence suggests that the population is a natural one.

The first mention of *P. trifoliatum* from Michigan was made by N. H. Winchell, in a progress report compiled by A. Winchell for the geological survey of the state that involved, among other things, a section on plants of the lower peninsula. He listed the species for southern Michigan and stated that his report was based on a specimen at the University of Michigan herbarium. Beal's flora (1905) repeated Winchell's report, as did other early lists. Gleason (1926) included the species, apparently on Beal's authority, in his keys to Michigan vascular plants. All mentions of Michigan in the range of *P. trifoliatum* by subsequent regional floras and popular wildflower guides appear to have their basis in Winchell's first report.

Deam, in his Indiana flora (1940), rejected the report because voucher

specimens for Winchell's listing were *not* at the University of Michigan herbarium. Fruitless searches have been made at that herbarium, but those at Michigan State University and Cranbrook Institute of Science have gone better. Besides overlooked specimens representing new localities in other midwestern states, two specimens were found with Michigan Agricultural College labels proclaiming "Habitat: Lansing." One specimen afforded no additional locality information but the other, according to handwriting on the label, had been collected from the university botanical garden and was presumably cultivated there. Whether the first specimen was also a collection from the garden or represents a natural occurrence or escape from cultivation in the vicinity of Lansing cannot be answered. At Cranbrook Institute of Science are two specimens collected by Farwell in Detroit, Wayne County, on different years around the turn of the century. Both were called *P. trifolius* but are actually *P. stipulatus*. One of these was cited by Farwell as a first record of *P. trifolius* in the state (Rep. Mich. Acad. 6:212. 1905 ["1904"].)

Since no other substantiated reports of *P. trifolius* in Michigan are known, the Gourdneck population has been accepted by the Technical Advisory Committee for the Michigan Endangered Species program as the first verified native stand. The nearest reliable published report of the species from the Great Lakes region comes from near Windsor, Ontario (Soper, 1962), 130 air miles east (Fig. 2). Because of the paucity of verified published reports and herbarium specimens representing presumably native stands in the Midwest, the species is currently listed as "threatened" in Michigan (Mich. Dept. of Natural Resources, 1982, unpubl.). Specimens from the Gourdneck population are deposited at the herbaria of Michigan State University and the University of Michigan.

ACKNOWLEDGMENTS

I am grateful to R. Gereau of Michigan State University and P. Thompson of Cranbrook Institute of Science for aid in locating specimens; E. G. Voss of the University of Michigan herbarium for nomenclatural and historical comments; and R. Brewer of Western Michigan University, W. H. Wagner of the University of Michigan, and an anonymous reviewer for examining the manuscript at various stages of development.

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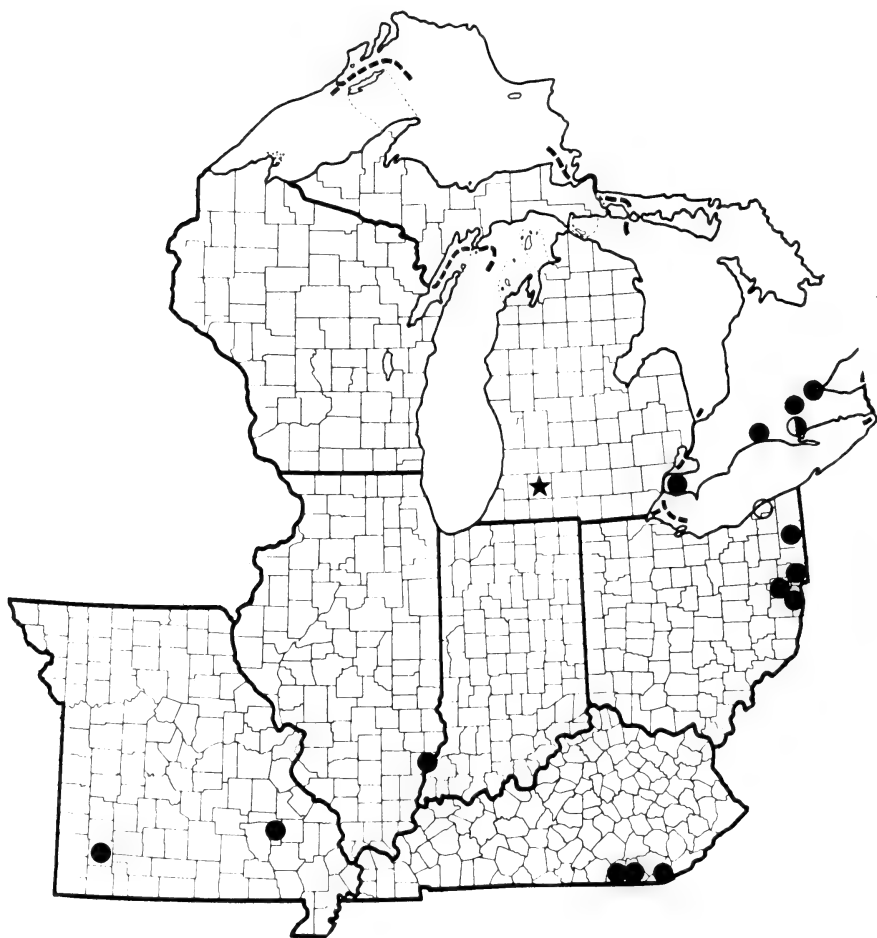


Fig. 2. Distribution of *Porteranthus trifolius* west of Appalachia; open circle = escape from cultivation; solid circles = presumably native populations (half-open circle represents both native and escaped populations); star = Kalamazoo Co. population. Based on personal communications, specimens at MICH, MSC, and OS, and published reports backed by vouchers, by Braun (1943) and Steyermark (1963). Additional information in Ballard (unpubl.)

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BARTONIA PANICULATA, NEW TO MICHIGAN

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Bartonia paniculata (Michx.) Muhl. (Screw-stem) is a member of a small genus of four species endemic to eastern North America. Although the plant is small and fairly inconspicuous, it is of considerable interest phytogeographically. Until the last few years the known range of *Bartonia paniculata* subsp. *paniculata* was from southern New England south along the coast to Florida then west to Louisiana, extending inland in the south to Kentucky and Arkansas (Gillett 1959). There is also a record in extreme southern Illinois mapped by Mohlenbrock & Ladd (1978). In 1973 it was collected in Muskoka District Ontario (Reznicek & Whiting 1976).

On August 26, 1983, I collected *B. paniculata* subsp. *paniculata* in Luce County, Michigan. This extends its range about 400 km west and north of the Ontario locations, which themselves are disjunct about 600 km from the nearest stations on the east coast (Reznicek & Whiting 1976). Since *B. paniculata* has been discovered in these two strikingly disjunct inland locations it deserves inclusion in the group of plants often referred to as "coastal plain disjuncts," although its occurrence in northern Michigan is away from the major concentration of coastal plain species in southwestern Michigan (Voss, 1972).

In Luce County *B. paniculata* grows in sphagnum on the edge of a string in a patterned bog. The summer of 1983 was very dry in eastern Upper Michigan and perhaps in wetter years there may be more plants than the 50–75 that were observed. The bog is on a large glacial outwash plain, a landform which covers much of the central Upper Peninsula. The patterning of this bog has some of the longest strings and flarks that I have seen in Michigan patterned bogs.

Growing in the flarks were *Scirpus subterminalis*, *Eriocaulon septangulare*, and *Menyanthes trifoliata*. On the strings in the adjacent bog areas were *Carex exilis*, *C. oligosperma*, *Hypericum kalmianum*, *Rhynchospora alba*, *R. fusca*, *Muhlenbergia uniflora*, *Aster nemoralis* and occasional stunted *Larix laricina*.

From my experience in the past several years, the shorelines of various glacial outwash areas and higher level glacial lake stages offer abundant possibilities to discover rare plants and disjunct occurrences of species. Further research and fieldwork is needed to understand the origin of these rare and interesting species and how these occurrences interrelate with the glacial history that produced them.

Michigan Collections: Luce Co., ca. 15 m. N of Newberry, August 26, 1983, Don Henson 1560 (MICH, WIS).

I thank A. A. Reznicek for confirming the plants as *Bartonia paniculata* and determining them to be subsp. *paniculata*, William R. Gillette for assistance in the field, and Michael Penskar for initial location information on this bog.

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245 OAK FOREST SUCCESSION IN THE OAKLAND UNIVERSITY NATURE TRAILS AREA, OAKLAND COUNTY, MICHIGAN

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The 1500-acre Oakland University campus includes nature trails through several hundred acres of undeveloped land. These trails, as well as those in the adjacent Auburn Hills Civic Center Park, offer access to natural areas close to the greater metropolitan Detroit area. The purpose of this paper is to describe the Oakland University Nature Trails area with respect to pre-settlement vegetation, post-settlement land usage, and current successional status of the upland oak forest.

Location, topography, and soils. The southwestern corner of the Oakland University campus (Oakland Co., Pontiac Twp., T3N, R10E, sec. 13, 24; Avon Twp., T3N, R11E, sec. 18, 19), bounded on the north by Lonedale Rd., west by Squirrel Rd., south by Butler Rd., and on the east by Katke-Cousins Golf Course, consists of approximately 240 acres of undeveloped land (Fig. 1). The nature trails begin at the east end of Lonedale Rd., cross Galloway Creek, and continue through an upland area with 150 acres of forest. The highest point is 283 m above sea level (30 m above the creek) at the northern edge of the forest (Fig. 2).

The soils are of glacial origin (USDA, 1982). The soil of the upland wooded area is Marlette loam on 12–35% slope, with low permeability, rapid runoff, and acid conditions [pH = 5.5 in 20 of 28 samples (two per transect—see methods); pH range 4.5–6.0, as measured with a Corning pH meter]. The soil of the abandoned fields consists primarily of Arkport loamy fine sand (6–12% slopes), a slightly richer soil with rapid runoff and medium permeability, and the soil of the low-lying poorly drained areas is Sloan silt loam.

Pre-settlement vegetation and post-settlement land use. The first Government Land Office surveys and the first permanent settlement in Avon township occurred in 1817. Surveys in the vicinity of the study site (Fig. 1) noted many occurrences of “prairie,” “wet prairie,” and brooks and streams. The area near Galloway Creek was described as “wet prairie,” and the line between Sec. 24 and 19 noted a “tamarack swamp.” The prairie grass, turkeyfoot *Andropogon gerardi*, can still be found east of Library Drive, and tamarack (*Larix laricina*) persists in other low areas. The survey also noted several “Indian path(s)” in the general vicinity (T3N, R10E, sec. 23; T3N, R11E, sec. 7, 8, 20).

Most of the upland area contained black oak (*Quercus velutina*) and white oak (*Quercus alba*). The study site was described as “poor hilly oak land” and “poor hilly land badly timbered.” The eastern side of Sec. 13,

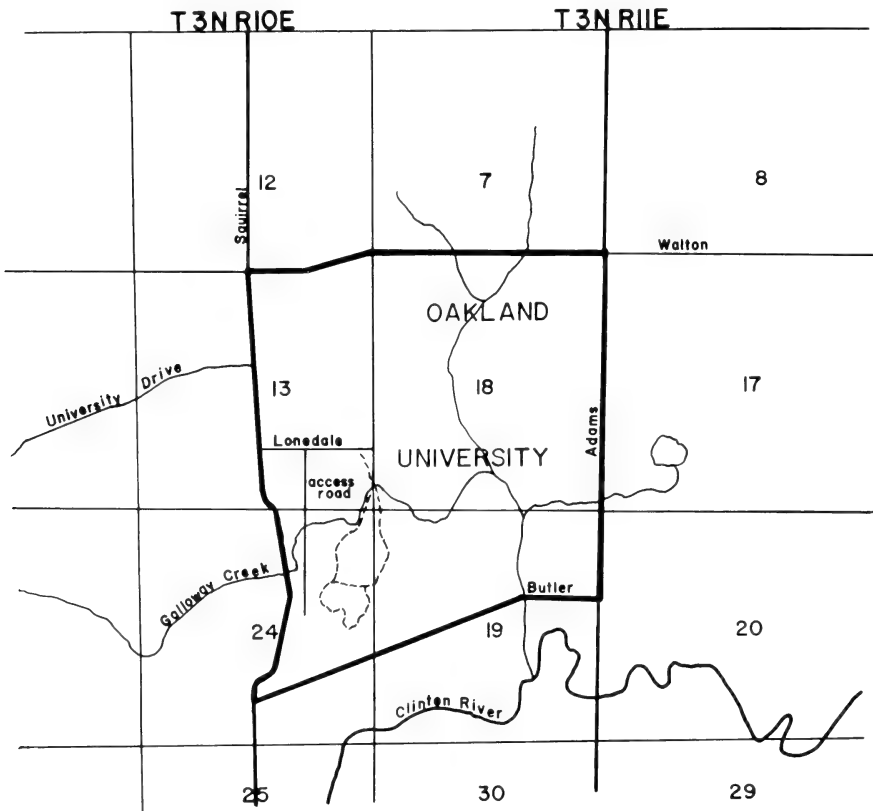


Fig. 1. Oakland University Nature Trails area. Trails are shown by dotted lines.

now the location of most campus buildings, was described as “poor hilly stony land” with “timber oak.”

Although surveyors were not unbiased in their choice of recorded trees (Bourdo, 1956), the Government Land Office surveys can be used for a more quantitative description of the former forest. The surveys of Sec. 13, 24, 18, and 19 ($N=41$ trees) showed 71% white oak, 22% black oak, 2% red oak (*Quercus rubra*), and 5% aspen (*Populus tremuloides*). In general, the white oak were larger than the black oak ($\bar{X}=53$ cm for white oak, 37 cm for black oak; largest=91 cm for white oak, 61 cm for black oak).

Sixty years after the survey, Durant (1877) noted that many areas of Avon Twp. had been logged and were farmed, although in the southern portion of the township, many trees “two to four feet through” were still present.

In 1908, John Dodge purchased the first of nine farms to form the Meadow Brook estate. Later, Alfred and Matilda Dodge Wilson raised livestock, grew crops, and operated an apple orchard on the estate (pers. comm., Marie Stomzand, Meadow Brook Hall Archives Committee). Meadow Brook Hall was completed on the east side in 1929. In 1957, the estate

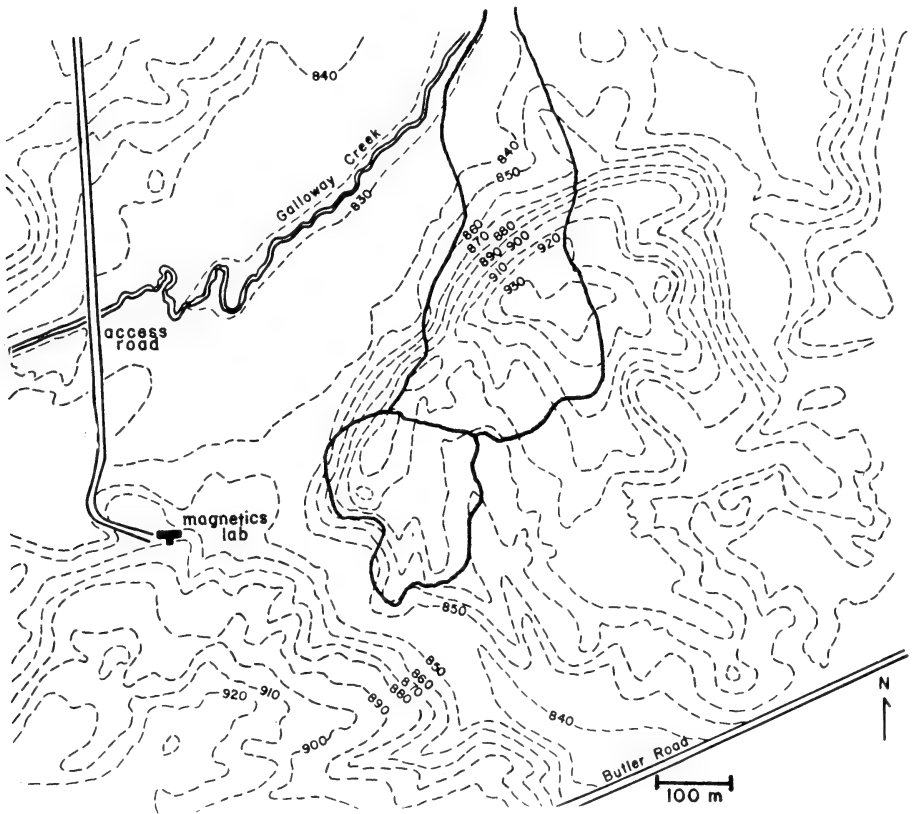


Fig. 2. Topographic map of Nature Trails area. Contour interval is 10 feet. Trails are indicated by solid lines.

became Michigan State University-Oakland (renamed Oakland University in 1963).

Since that time, several additional changes have occurred. A small nursery is now located in the west, south of Galloway Creek. In 1964, Kettering Magnetics Laboratory and its access road were built in the south-west corner, and Katke-Cousins Golf Course was completed in 1975 (Fig. 3). The nature trails were completed in 1976.

METHODS

To determine the species composition, density, basal area, and frequency of trees, fourteen 10 m wide transects ranging in length from 50 m to 170 m (total of 14,980 m² and 1890 trees) were surveyed during summer 1982 and spring 1983 (Fig. 4). Transects were located to minimize elevational and vegetational changes within the transect, and to distribute the transects throughout the upland oak forest. Each transect was divided into 10 m × 10 m plots. The forest was divided into three areas (south, central, north) for vegetational analysis, using the trails as reference. The northern and central areas each contained 5 transects, and the southern area contained 4 transects (Fig. 4).



Fig. 3. Aerial photograph of the study site. Galloway Creek is shown in the northwest corner with the Magnetics Building in the west, the tree nursery just south of Galloway Creek, Butler Road in the southeast corner and Katke-Cousins Golf Course north of Butler Road.

Within each transect each tree >3 cm dbh (diameter at 1.4 m above ground) was identified and measured for dbh. Every fifth tree >9 cm dbh was cored with an increment borer .3–.5 m above ground to determine tree age.

Trees in each of the three areas were further classified as overstory (>20.3 cm dbh) or understory (<20.3 cm dbh) to examine the relative amount of disturbance in each area. Importance values (IV) were determined by the methods of Curtis (1959), where $IV = (\text{relative frequency} + \text{relative density} + \text{relative basal area})/3$. Relative basal area is the basal area of a species as a percentage of the total basal area for all species. The basal area is the cross-sectional area of the tree trunk at 1.4 m. Relative density is the number of trees of a species expressed as a percentage of the total number of trees. Relative frequency is the frequency of one species as a percentage of the sum of frequencies of all species. Frequency is the percent of total plots containing at least one rooted individual of a given species. Herbaceous and shrubby species occurring in each transect in May–June 1983 were used as site indicators of disturbance.

Forest boundaries, trails, roads, and Galloway Creek were mapped using an aerial photograph (Fig. 3) and topographic maps. Nomenclature follows Barnes and Wagner (1981).

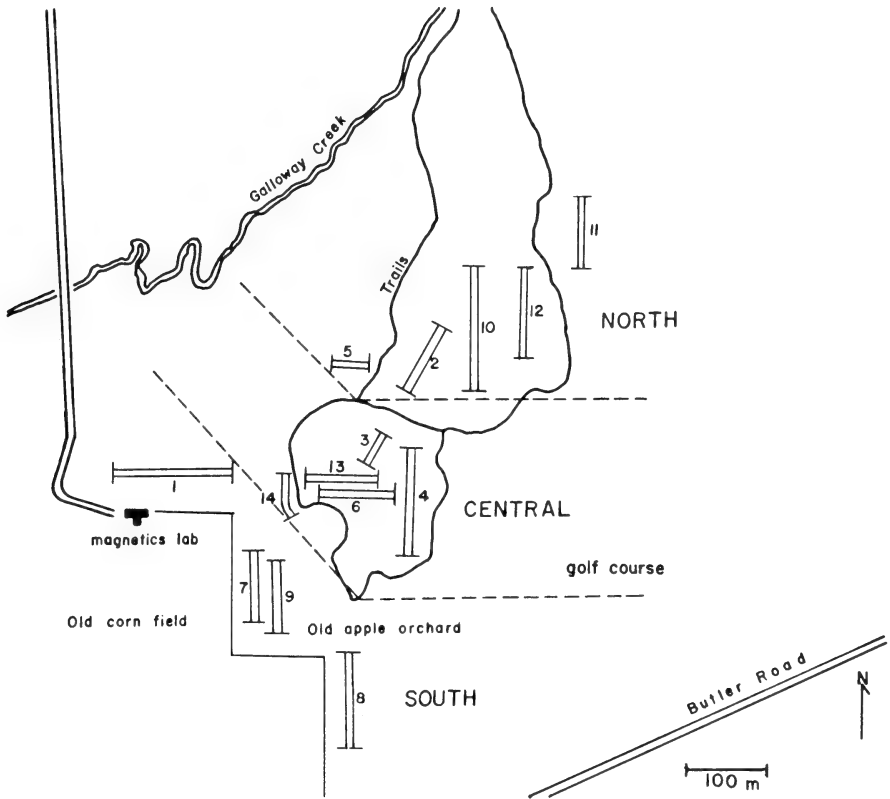


Fig. 4. Transects in study site.

RESULTS AND DISCUSSION

In 1982, the study site was a mosaic of early and mid-successional oak associations, differing primarily in the understory composition and in the proportions of white oak, black oak, and red oak in the overstory. Major understory trees included black cherry (*Prunus serotina*), red maple (*Acer rubrum*), sassafras (*Sassafras albidum*), and witch-hazel (*Hamamelis virginiana*). This mosaic was the result of initial logging and many small subsequent disturbances.

The mean age of all overstory trees was 102 years (Table 1); thus, logging occurred in this area about 1880. Several trees were considerably older (Table 1); the oldest cored tree was a red oak (161 years). In general, the oldest trees occurred in transects located on steep slopes (transects 5, 7) where logging may have been difficult. Transects in more accessible areas had younger trees in the overstory (transect 8, $\bar{X} = 74$ years; transect 12, $\bar{X} = 71$ years). Although there were differences among transects, the mean age of overstory trees did not differ significantly among the northern, central, and southern areas ($p < 0.10$, ANOVA).

TABLE 1. Age mean and range for each species in overstory and understory in each area.

	South			Central			North		
	N	\bar{X} age	range	N	\bar{X} age	range	N	\bar{X} age	range
Overstory species									
<i>Quercus alba</i>	5	104	67-139	7	102	63-132	8	107	90-141
<i>Quercus velutina</i>	5	101	65-128	11	108	82-144	3	97	37-128
<i>Quercus rubra</i>	-	-	-	1	101	-	1	161	-
<i>Prunus serotina</i>	2	33	30-35	2	85	81-88	2	74	71-76
<i>Acer rubrum</i>	-	-	-	1	48	-	4	66	41-112
<i>Sassafras rubrum</i>	-	-	-	-	-	-	2	66	42-90
<i>Malus pumila</i>	1	66	-	-	-	-	-	-	-
<i>Juglans nigra</i>	1	58	-	-	-	-	-	-	-
Understory species									
<i>Quercus alba</i>	1	26	-	4	88	66-121	2	50	25-74
<i>Quercus velutina</i>	1	32	-	-	-	-	4	33	31-37
<i>Quercus rubra</i>	5	28	18-33	-	-	-	-	-	-
<i>Prunus serotina</i>	5	30	19-55	5	44	11-66	5	37	22-50
<i>Acer rubrum</i>	-	-	-	1	26	-	2	24	20-28
<i>Sassafras albidum</i>	-	-	-	-	-	-	3	40	30-53

The mean dbh of white oak in 1982 (31.5 cm) was considerably smaller than in 1817. The largest 1982 white oak (59 cm) was about the size of the average 1817 white oak (53 cm). The mean diameter for black oak was similar in the two years (37 cm in 1817; 32.1 cm in 1982), although in contrast to white oak, the largest black oak was recorded in 1982 (78 cm in 1982; 61 cm in 1817). Thus, although the surveyors noted the upland areas as "badly timbered," the trees at that time, though perhaps in less dense stands, were as large or larger than trees in the current forest. The smaller size of current trees was most likely the result of more frequent disturbance of the area since 1880 than before settlement in 1817. Fires were the most likely pre-settlement disturbance, favoring maintenance of both the prairies and oak forest (Spurr & Barnes, 1980).

Several lines of evidence were used to determine the amount and type of disturbances since 1880. Auclair and Cottam (1971) used both basal area density and stem density of the overstory as estimates of disturbance in Wisconsin oak forests. Using 8 inches (20.3 cm dbh) as the overstory minimum, they interpreted stands with an overstory basal area >18000 in²/acre (28.7 cm²/m²) and with low overstory stem density as relatively undisturbed. Large overstory basal area and low overstory stem density occur when the canopy is composed of a few large trees. The proportion of stems in the overstory, remaining evidence of man-made disturbances, knowledge of the life histories of both woody and herbaceous species in the area, and patterns of woody plant species recruitment were also used as indicators of disturbance. Based on these criteria, the central area of the study site (Fig. 4) was the least disturbed and the southern area was the most disturbed.

TABLE 2. Importance values (IV), relative density (RD), relative frequency (RF), and relative basal area (RBA) for each species in the central area. O=overstory; U=understory.

Species	IV		RD		RF		RBA	
	O	U	O	U	O	U	O	U
<i>Quercus alba</i>	37.4	3.0	40.7	1.5	34.3	3.8	37.3	3.6
<i>Quercus velutina</i>	42.9	0.9	40.7	0.6	41.8	0.9	46.1	1.1
<i>Quercus rubra</i>	0	0.8	0	0.3	1.5	0	0	2.1
<i>Prunus serotina</i>	16.7	44.8	16.7	46.7	17.9	34.9	15.4	52.7
<i>Acer rubrum</i>	2.6	20.7	1.9	21.3	4.5	21.7	1.3	19.0
<i>Sassafras albidum</i>	0	7.2	0	6.8	0	9.4	0	5.4
<i>Hamamelis virginiana</i>	0	9.4	0	11.5	0	10.4	0	6.2
<i>Carya ovata</i>	0	0.4	0	0.3	0	0.9	0	0.1
<i>Acer saccharum</i>	0	0.1	0	0.3	0	0.9	0	0.1
<i>Cornus florida</i>	0	2.2	0	2.4	0	2.8	0	1.3
<i>Carpinus caroliniana</i>	0	1.4	0	0.9	0	2.8	0	1.4
<i>Tilia americana</i>	0	0.7	0	0.6	0	0.9	0	0.5
<i>Fraxinus americana</i>	0	2.8	0	2.7	0	2.8	0	2.9
<i>Amelanchier arborea</i>	0	0.4	0	0.4	0	0.9	0	0.1
<i>Fraxinus nigra</i>	0	0.5	0	0.3	0	0.9	0	0.2
<i>Crataegus</i> spp.	0	1.8	0	1.2	0	2.8	0	1.4
<i>Ulmus americana</i>	0	1.7	0	1.2	0	2.8	0	0.7
<i>Vitis</i> spp.	0	1.0	0	1.2	0	0.9	0	1.0

	Overstory	Understory
number of trees	108	338
total basal area (sq cm)	4296	2153
basal area density (sq cm/sq m)	31.3	3.1
density (stems/sq m)	.071	.023

Central area. The central area had the largest overstory basal area, the smallest overstory stem density, and the largest proportion of trees in the overstory (Table 2). This area also had the lowest overstory species richness (4 species), and the two major canopy species, black oak and white oak, had the lowest recruitment (number of stems in the understory) in this area. Several shade-tolerant species occurred in the understory, including shagbark hickory (*Carya ovata*), basswood (*Tilia americana*), musclewood (*Carpinus caroliniana*), witch-hazel (*Hamamelis virginiana*), flowering dogwood (*Cornus florida*), and sugar maple (*Acer saccharum*). There were relatively few weedy herbaceous or woody species, although sassafras was an abundant understory tree.

The black oaks in this area consisted of individuals with both single trunks and multiple trunks. The latter most likely resulted from cutting around 1890 with subsequent resprouting from stumps. For example, in transect 13, multiple trunk trees had a mean age of 89 years (range 82–96) compared to 110 years for two single trunk black oaks. White oak in this area were slightly smaller than black oak. Many of the understory white oaks were also quite old; two 17–18 cm dbh stems were 86 and 121 years in age. Black oak and white oak were the dominant canopy trees (combined overstory IV = 80; Table 2), but very little recruitment was occurring (combined

understory IV = 4). Although the two species had similar overstory densities, white oak understory stem density was twice that of black oak (Table 2).

Black cherry and red maple trees were not abundant in the overstory, but they may have served as source trees for the large numbers of these species in the understory.

Wintergreen (*Gaultheria procumbens*), black huckleberry (*Gaylussacia baccata*), and blueberry (*Vaccinium angustifolium*), all acid indicators, occurred in the central area, and spring flora including wild geranium (*Geranium maculatum*), false Solomon's seal (*Smilacina racemosa*), false lily-of-the-valley (*Maianthemum canadense*), mayapple (*Podophyllum peltatum*), and trillium (*Trillium grandiflorum*) were found locally throughout the study site.

Southern area. The southern area was the most open and disturbed of the three areas, based on its low overstory basal area, high stem density, and large number of weedy herbaceous and woody species (Table 3). Disturbance resulted from the cultivation and subsequent abandonment of an apple orchard, and nearby construction.

The aerial photograph (Fig. 3) showed many gaps in the southern forested area. Several low-lying regions not sampled contained wet-adapted species such as red-berried elder (*Sambucus pubens*), jack-in-the-pulpit (*Arisaema triphyllum*), wild black currant (*Ribes americanum*), and skunk cabbage (*Symplocarpus foetidus*), as well as a large (86 cm dbh) black locust (*Robinia pseudoacacia*).

The overstory in the southern area varied in age (Table 1). Transect 7 contained old overstory white oak (\bar{X} = 135 years) and black oak (\bar{X} = 116 years). Transects 8 and 9 were in the area of the apple orchard. One apple tree cored was 66 years in age, dating the orchard beginning around 1916. The mean age for understory red oak in these two transects was 28 years, suggesting orchard abandonment around 1950.

Transect 1, closest to the Magnetics Lab, had overstory white and red oak about 90 years in age, but also contained the most weedy or shade-intolerant woody plants (Table 3). These included elm (*Ulmus americana*), sassafras, hawthorne (*Crataegus* spp.), black locust, box elder (*Acer negundo*), trembling aspen, red mulberry (*Morus rubra*), and poison ivy (*Toxicodendron radicans*). The mean age of the understory black cherry in this transect was 26 years, most likely a result of recruitment following construction of the Magnetics Lab.

Although important in the overstory, both black oak and white oak were poorly represented in the understory (Table 3). Relative to its overstory density, black oak reproduction was considerably greater than that of white oak. Red oak reached its highest IV in this area, and numerous red oak saplings occurred in canopy openings, near the forest edge, and in the abandoned orchard. Our documentation of red oak presence in exposed areas is consistent with Hammitt's 1969 study of Radrick Forest, an oak-hickory forest in southeastern Michigan with these same three oak species.

Northern area. This area was intermediate in measures of disturbance (Table 4). Although several species occurred in the overstory, white oak was

TABLE 3. Importance values (IV), relative density (RD), relative frequency (RF), and relative basal area (RBA) for each species in the southern area. O = overstory; U = understory.

Species	IV		RD		RF		RBA	
	O	U	O	U	O	U	O	U
<i>Quercus alba</i>	33.4	2.7	33.0	1.5	25.4	4.8	41.8	1.7
<i>Quercus velutina</i>	16.7	9.0	18.1	3.6	25.4	6.9	6.6	16.4
<i>Quercus rubra</i>	24.4	19.5	24.5	18.5	23.6	19.3	25.1	20.6
<i>Prunus serotina</i>	12.9	39.3	14.9	50.5	10.9	28.9	12.9	38.6
<i>Acer rubrum</i>	0	1.3	0	1.0	0	2.1	0	0.7
<i>Sassafras albidum</i>	0	2.5	0	4.1	0	0.8	0	2.7
<i>Hamamelis virginiana</i>	0	1.1	0	1.8	0	0.8	0	0.8
<i>Carya ovata</i>	3.5	2.1	2.1	1.3	3.7	3.4	4.7	0.9
<i>Carpinus caroliniana</i>	0	0.5	0	0.5	0	0.7	0	0.4
<i>Tilia americana</i>	0	0.6	0	0.7	0	1.4	0	0.6
<i>Fraxinus americana</i>	0	0.3	0	0.3	0	0.7	0	0.2
<i>Ostrya virginiana</i>	0	0.1	0	0.2	0	0.7	0	0
<i>Juglans nigra</i>	3.3	1.4	2.1	0.2	3.7	0.7	4.0	0.2
<i>Malus pumila</i>	2.5	3.7	2.1	1.8	3.7	4.8	1.7	4.4
<i>Ulmus americana</i>	1.2	7.0	1.1	5.1	1.8	11.7	0.8	4.3
<i>Crataegus</i> spp.	1.3	4.2	1.1	3.1	1.8	6.3	1.0	3.3
<i>Robinia pseudoacacia</i>	0	1.5	0	2.5	0	0.8	0	1.2
<i>Populus tremuloides</i>	0	1.3	0	1.0	0	2.1	0	0.9
<i>Acer negundo</i>	1.3	0	1.1	0	0	0.7	1.4	0
<i>Morus rubra</i>	0	0.8	0	0.8	0	2.1	0	0.9
<i>Prunus virginiana</i>	0	0.2	0	2.1	0	0.7	0	1.0
<i>Vitis</i> spp.	0	0.1	0	0.2	0	0.7	0	0.1

	Overstory	Understory
number of trees	94	606
total basal area (sq cm)	2714	4551
basal area density (sq cm/sq m)	21.7	5.5
density (stems/sq m)	.127	.019

the dominant species. The mean age of white oak was 107 years, and century-old white oaks occurred in all transects. The oldest trees of several species, including white oak, red oak, red maple, and sassafras (Table 1) all occurred in the northern area.

Selective removal of some black oak took place around 1948, as suggested by four trees with multiple trunks (stump sprouts) in transect 12 with a mean age of only 33 years. Cores of white oak in this area also showed greater annual ring width growth approximately 34 years ago, suggesting release from suppression with the removal of the black oaks. Only a small amount of recruitment of white and black oak occurred (Table 4). As in the southern area, black oak contributed more to the understory, relative to its proportion in the overstory, than white oak.

The most important understory species were black cherry and red maple (Table 4). Red maple had a high relative density and low relative frequency, indicating a clumped spatial pattern. Sassafras and witch-hazel were also important understory species, reaching their highest relative density here, and sassafras as old as 90 years were cored. The high density of sassafras

TABLE 4. Importance values (IV), relative density (RD), relative frequency (RF), and relative basal area (RBA) for each species in the northern area. O = overstory; U = understory.

Species	IV		RD		RF		RBA	
	O	U	O	U	O	U	O	U
<i>Quercus alba</i>	42.9	4.4	46.1	2.3	36.4	5.2	46.2	5.8
<i>Quercus velutina</i>	19.4	5.1	18.0	3.7	19.7	5.8	20.5	5.7
<i>Quercus rubra</i>	4.6	1.9	4.7	1.5	4.6	1.8	4.9	2.4
<i>Prunus serotina</i>	14.5	18.0	13.3	16.2	18.2	20.2	11.9	17.7
<i>Acer rubrum</i>	11.7	39.4	10.9	48.2	15.2	28.3	8.9	41.6
<i>Sassafras albidum</i>	7.2	9.7	8.6	10.0	6.0	6.9	7.1	12.3
<i>Hamamelis virginiana</i>	0	10.6	0	12.2	0	12.1	0	7.5
<i>Carya ovata</i>	0	0.3	0	0.2	0	0.6	0	0.2
<i>Cornus florida</i>	0	2.5	0	2.0	0	2.9	0	2.6
<i>Tilia americana</i>	0.4	2.7	0.8	1.0	0	5.2	0.5	1.2
<i>Amelanchier arborea</i>	0	2.5	0	1.0	0	5.8	0	0.8
<i>Crataegus</i> spp.	0	0.3	0	0.2	0	0.6	0	0.1
<i>Ulmus americana</i>	0	1.9	0	1.5	0	2.9	0	1.4
<i>Malus pumila</i>	0	0.4	0	0.2	0	0.6	0	0.5
<i>Morus rubra</i>	0	0.3	0	0.2	0	0.6	0	0.1

	Overstory	Understory
number of trees	128	616
total basal area (sq cm)	4614	3671
basal area density (sq cm/sq m)	22.7	4.5
density (stems/sq m)	.111	.023

may have resulted from its clonal spread over several decades (especially with black oak removal), resulting in many stems 30–53 years in age.

General observations. The Oakland University Nature Trails area was an oak forest with white oak and black oak dominant in the overstory, and with black cherry and red maple as the dominant understory species. Sassafras and witch-hazel were also present.

The relative densities of the three oak species in 1982 (white oak: black oak:red oak—41%:25%:9%) showed less white oak and more red oak, relative to the 1817 surveys (71%:22%:2%). The red oak was associated with recent disturbance on the south side of the study site. The decrease in the proportion of white oak is difficult to explain, especially with selective black oak removal. The greater proportion of black oak than white oak in the understory (relative to overstory densities) as well as the faster growth rate of black oak relative to white oak (Auclair & Cottam, 1971) indicate that black oak may be favored in the present conditions.

The 1982 ratios were very similar to those of Radrick Forest in southeastern Michigan (44%:27%:15%), a 40 acre oak-hickory forest logged in the late 1820s (Hammit, 1969). These two sites were also similar in the lack of oak reproduction, and in the abundance of red maple and black cherry in the understory. Radrick Forest differed from the Oakland study site in the large number of sugar maple seedlings. Oak forests have been reported both with and without abundant sugar maple in the understory (Auclair & Cottam,

1971). The low sugar maple density at Oakland may be associated with the low number of source trees in the vicinity.

The major understory species in our study site were black cherry and red maple. The oldest black cherry occurred in the central area and the highest relative density of this species occurred there and in the southern area. Black cherry is a common understory tree in southern Wisconsin oak forests (Auclair & Cottam, 1971). It is capable of colonizing disturbed sites rapidly and can persist through later stages of succession. The black cherry in the central and northern areas occurred in both the overstory as well as understory, whereas in the southern area, it was predominantly in small size classes and associated with the disturbance from construction.

In contrast, the oldest red maple occurred in the northern area and red maple also reached its highest relative density there, with less in the central area and very little in the southern area. The low density of red maple in this latter area may have been the result of a low density of source trees in the southern and central areas.

The role of red maple in stand development is not clear. Red maple is an effective early colonizer and is intermediate in shade tolerance (Barnes & Wagner, 1981). Red maple has been interpreted as a subordinate and understory species in oak woods in Connecticut (Olson, 1965). It has also been viewed as a transitional species from an oak to a maple-basswood forest in southern Wisconsin (Larsen, 1953; Auclair & Cottam, 1971).

Many factors including the relatively young age of the oaks and recruitment patterns complicated by past local disturbances make prediction of future changes in this forest difficult. Although the canopy oaks were over a century old, oaks may live as long as 500–600 years (Hosie, 1979; Barnes & Wagner, 1981). Maintenance of oak forests in the past was dependent on fires (Spurr and Barnes, 1980) and fires have occurred in this area. "Burnt timberland" was noted in 1817 in Sec. 14 (T3N, R10E) and fire scars occurred in annual rings in trees cored in the study area. White oak and black oak were both abundant in the overstory but recruitment was low. Red oak was abundant only in the southern area, and red oak reproduction was greatest in the abandoned apple orchard. Later successional, more shade-tolerant species such as basswood and sugar maple were not present in large numbers in the understory, and beech was totally absent.

Given the acidic soil, the control of fires in the vicinity, the paucity of later successional species, and the long lifespan of oaks, this area will likely remain an oak woods similar to its present day composition for several decades as the current overstory continues to mature. The relative importance of different tree species will depend on the type, frequency, and intensity of future disturbance.

SUMMARY

The Oakland University campus, near Detroit in southeastern Michigan, includes a 150-acre natural area with trails through an upland oak forest. The purpose of this study was to

describe this oak forest with respect to pre-settlement vegetation, post-settlement land usage, and current successional status.

The terrain and overstory composition were similar to those described in General Land Office Surveys of 1817. The area was logged around 1880 and has experienced minor disturbances since that time.

The current forest consisted of an overstory of black oak and white oak and an understory of red maple and black cherry as well as sassafras and witch-hazel. The central part of the forest, with the highest overstory basal area and lowest overstory stem density, was the least disturbed. Overstory black oaks were as old as 144 years, and several shade-tolerant species such as flowering dogwood and sugar maple occurred in the understory. Oak reproduction was poor in both the northern and central parts of the forest. In the southern part, remnants of an apple orchard planted in 1916 and abandoned about 1950 were obscured by large numbers of small red oak and red maple that appeared after abandonment and that increased in number with nearby building construction in 1964. Spring flora such as mayapple, false Solomon's seal, and trillium were found in upland areas; wild black currant, jack-in-the-pulpit, and skunk cabbage occurred in lower areas. Given the young age of the overstory oaks, the control of fires, and the slow recruitment of more shade-tolerant species, this area will remain an oak forest for the next several decades, with the type and frequency of disturbances controlling the relative importance of the existing species.

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A KEY TO THE RUSHES (JUNCUS SPP.) OF MINNESOTA

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In creating this key to the rushes of Minnesota, it became apparent that there are discrepancies in the major floristic works covering the region. Species are often cited from Minnesota yet there are no specimens, other species are found in Minnesota but not cited. In this paper I have tried to correct these discrepancies, identify rarities, and discuss certain recently proposed taxonomic changes, along with providing a key to the species.

Two species, often reported from Minnesota, probably do not occur there. Early reports of *Juncus acuminatus* Michaux can be discounted: the report in Upham (1884), who cites no specimens, was based on a misidentified specimen (Rosendahl & Butters, 1916), while other reports by MacMillan (1892), based on *Ballard* 280 (MIN), and by W. A. Wheeler (1901), based on *Ballard* 2743 (MIN), are also misidentified and are, in fact, collections of *J. alpinoarticulatus* Chaix in Villars. More recent reports by Fernald (1950), Gleason (1952), and Gleason & Cronquist (1963), who cite no specimens, are probably based on the early reports or misidentified specimens. Moreover, reports of *J. brachycephalus* (Engelm.) Buchenau by Moore & Tryon (1946) and by Gleason & Cronquist (1963), who cite no specimens, are probably based on specimens such as *Rosendahl*, *Butters*, & *Moyle* 4060 (MIN) and *Lakela* 12179 (MIN) which are labeled *J. brachycephalus* but are actually *J. alpinoarticulatus*. I have not seen the specimen indicated for Minnesota by Barkley (1977), but I believe it is also misidentified since I have seen no authentic specimens of this species at A, GH, MIN, NDA, NY, or WIS.

Although two species are here excluded from Minnesota's flora, three others need to be added. Stuckey (1981) has shown that *J. compressus* Jacq. occurs in Minnesota (see specimens cited). *Juncus longistylis* Torrey is now known from five counties in northwestern Minnesota (see specimens cited), although it is not reported from the state, except by Barkley (1977). A third new species, *J. brachycarpus* Engelm., has been collected only once, in Blue Earth county (see specimens cited).

Four additional species are rare in Minnesota. *Juncus marginatus* Rostkov and *J. articulatus* L. are both known from single locations just north of St. Paul (see specimens cited). *Juncus stygius* L. var. *americanus* Buchenau was long known from only two collections, but recently G. A. Wheeler & Glaser (1979) and W. R. Smith have greatly extended its range in Minnesota (see specimens cited here and in G. A. Wheeler & Glaser 1979). As Stuckey (1980) has demonstrated, *J. gerardii* Loisel is an apparently recent addition to the state flora (see specimen cited), probably arriving in the past 150 years.

Three recently proposed taxonomic changes which affect Minnesota

species are not being followed. Hämet-Ahti, in a revision of the eastern North American *Juncus effusus* L. complex (Hämet-Ahti, 1980a), proposed recognizing four taxa [*J. pylaei* Laharpe, *J. conglomeratus* L., *J. effusus* L. ssp. *effusus* and *J. effusus* ssp. *solutus* (Fern. & Wieg.) Hämet-Ahti], two of which occur in Minnesota (*Juncus pylaei* and *J. effusus* ssp. *solutus*). She separates these two species with the following characters:

1. Stems and lowest bract coarsely sulcate with 10–20 longitudinal ridges, epidermal cells on the ridges distinctly larger than the others. *J. pylaei*
1. Stems and lowest bract smooth to finely striate with 30–60 small longitudinal ridges, epidermal cells \pm uniform. *J. effusus* ssp. *solutus*

Stem anatomy is an important character in the Juncaceae, but it is apparently the only reliable character used to separate these two taxa. This presents a problem. Field identification of these taxa, at low magnification, would be nearly impossible. In addition, the number of ridges and their size can be obscured when the stem wrinkles on drying. The inherent difficulty with using this character and the apparent lack of other differentia have prompted me to use the treatment of Gleason & Cronquist (1963), which I find more acceptable. Following this treatment, all the Minnesota specimens are *J. effusus* L. var. *solutus* Fern. & Wieg.

Hermann (1975) has recently proposed transferring *J. dudleyi* Wieg. to *J. tenuis* Willd. as a variety, but he retains *J. interior* Wieg. as a distinct species. I find, on the other hand, that *J. tenuis* appears more closely related to *J. interior* than either one is to *J. dudleyi*. Both *J. tenuis* and *J. interior* have white, membranaceous auricles and nearly globose seeds with identical seed coat sculpturing, whereas *J. dudleyi* has yellow, cartilaginous auricles and more elongate seeds with a slightly different seed coat sculpturing. This group is obviously in need of revision. Until such a revision is made, I am recognizing these three taxa at the species rank.

Bovin (1979) has proposed transferring *J. balticus* Willd. var. *littoralis* Engelm. to *J. arcticus* Willd. He does this because he was "unable to establish a clear discontinuity between the two species [*J. balticus* and *J. arcticus*]." Although he may be correct, I am retaining the older and more common combination, *J. balticus* var. *littoralis*, until a more thorough study of the problem is made.

KEY TO THE SPECIES OF JUNCUS IN MINNESOTA

1. Inflorescence apparently lateral; leaves all basally inserted (subg. *Genuini*).
2. Involucral bract more than one half the height of the plant; stamens 6. *J. filiformis* L.
2. Involucral bract less than one half the height of the plant; stamens 3 or 6.
3. Stamens 3; culms arising from a short vertical rhizome; perianth segments green to stramineous. *J. effusus* L. var. *solutus* Fern. & Wieg.
3. Stamens 6; culms arising from a thick horizontal rhizome; perianth segments brown. *J. balticus* Willd. var. *littoralis* Engelm.

1. Inflorescence obviously terminal; some cauline leaves with blades.
4. Flowers borne singly at the ends of the inflorescence branches (except in a few specimens of *J. bufonius*), each flower subtended by two bracteoles; leaves not septate-nodulose.
5. Annual; leaf sheaths tapering to the blade, without an auricle (subg. *Potophylli*). *J. bufonius* L.
5. Perennial; leaf sheaths with an auricle (subg. *Pseudotenageia*).
6. Plants not caespitose; culms arising in tufts from an horizontal rhizome; perianth segments 2–2.5 mm long.
7. Capsules shorter than the perianth segments; anthers three times longer than the filaments. *J. gerardii* Loisel.
7. Capsules longer than the perianth segments; anthers subequal to the filaments. *J. compressus* Jacq.
6. Plants caespitose; culms arising from short inconspicuous rhizomes; perianth segments usually more than 2.5 mm long.
8. Leaf-blades terete, at least toward the apex; perianth segments erect, appressed to the capsule; seeds tailed or not.
9. Involucral bract 4–20 cm long; leaves involute near the sheath but becoming terete toward the apex; seeds 0.3–0.6 mm long, not distinctly tailed. *J. greenii* Oakes & Tuckerman
9. Involucral bract 1–3(–7) cm long; leaves terete throughout; seeds 0.8–1.4 mm long, distinctly tailed. *J. vaseyi* Engelm.
8. Leaf-blades channeled or involute; perianth segments ascending-spreading, not appressed to the capsule; seeds not tailed.
10. Auricles white, membranaceous; seeds usually 0.3–0.4 mm long.
11. Auricles prolonged 0.5–4.3 mm beyond the point of insertion. *J. tenuis* Willd.
11. Auricles not prolonged or prolonged 0.2 mm or less beyond the point of insertion. *J. interior* Wieg.
10. Auricles yellow, cartilaginous; seeds 0.4–0.5 mm long. *J. dudleyi* Wieg.
4. Flowers borne in glomerules (except *J. pelocarpus* in which the leaves are septate-nodulose), each flower not subtended by bracteoles; leaves septate-nodulose or not.
12. Leaf-blades flat, not septate-nodulose (subg. *Graminifolii*).
13. Stamens 3, reddish-brown; culms arising from a short rhizome; capsules 1.7–2.0 mm long, apically obtuse. *J. marginatus* Rostkov
13. Stamens 6, light yellow; culms arising from an elongate rhizome; capsules 4–5 mm long, apically acuminate. *J. longistylis* Torrey
12. Leaf-blades terete, involute or channeled, never flat, septate-nodulose or not.
14. Leaves not septate-nodulose (subg. *Alpini*). *J. stygius* L. var. *americanus* Buchenau
14. Leaves septate-nodulose (subg. *Septati*).
15. Flowers borne singly or in groups of 2 or 3; inflorescence one-fourth or more the height of the plant. *J. pelocarpus* E. Meyer
15. Flowers aggregated into glomerules of 2 or more flowers; inflorescence less than one-fourth the height of the plant.
16. Seeds 0.5–1.8 mm long, tailed.
17. Seeds 1.3–1.8 mm long; tails 0.25–0.42 mm long; glomerules hemispherical, mostly with 5 or more flowers. *J. canadensis* Gay
17. Seeds 1.0 mm long or less, tails 0.08–0.28 mm long; glomerules hemispherical or usually narrower, with 2–5 flowers. *J. brevicaudatus* (Engelm.) Fern.
16. Seeds 0.4–0.6 mm long, not tailed.
18. Stamens 3; glomerules spherical. *J. brachycarpus* Engelm.
18. Stamens 6; glomerules spherical or hemispherical.

19. Glomerules spherical; capsules lanceoloid; involucrel bract exceeding the inflorescence.
20. Outer perianth segments 3.0–4.6 mm long, distinctly longer than the inner segments, green to stramineous; glomerules often 1 cm or more in diam. *J. torrey* Cov.
20. Outer perianth segments 2.2–3.3 mm long, equal to or shorter than the inner segments, stramineous to tan; glomerules less than 1 cm in diam. *J. nodosus* L.
19. Glomerules hemispherical or narrower, capsules ellipsoid or ovoid; involucrel bract shorter than the inflorescence.
21. Inner perianth segments 1.4–2.5 mm long, obtuse to acuminate; inflorescence ascending. *J. alpinoarticulatus* Chaix in Villars¹
21. Inner perianth segments 2.1–2.5 mm long, acuminate; inflorescence spreading. *J. articulatus* L.

SPECIMENS CITED

(All specimens cited are at MIN).

Juncus articulatus. RAMSEY CO.: White Bear Lake nr. village, *Rosendahl & Rydberg* 5183.

Juncus brachycephalus. BLUE EARTH CO.: uplands W of Minneopa Creek, N. of Hwy 83, *D. L. Jacobs* 495.

Juncus compressus. KITTSON CO.: at Caribou, *J. W. Moore* 26083.

Juncus gerardii. MARTIN CO.: 1 mi. N of Fairmont, *J. W. Moore* 20689.

Juncus longistylis. CLAY CO.: Dower, *O. A. Stevens* 2598. KITTSON CO.: 10 mi. NE of Lancaster, *J. W. Moore* 24784; 3 mi. N of Halma, *J. W. Moore* 24738. NORMAN CO.: ca 2.5 mi. S of Norman-Polk county line, Hwy 32, *G. A. Wheeler* 2673; ½ mi. S of Syre, *J. W. Moore* 22621. PENNINGTON CO.: 9 m. S of Thief River Falls, *J. B. Moyle* 1320. POLK CO.: 3 mi. W of Fertile on road to Beltrami, *Thorne* 30890.

Juncus marginatus. ANOKA CO.: Moore Lake, *Rosendahl* 5475; *Rosendahl & Butters* 3621.

Juncus stygius var. *americanus*. CARLTON CO.: 2.5 mi. S of Wright, *W. R. Smith* 5392.

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GREEN SPLEENWORT (*ASPLENIUM VIRIDE*), A NEW WISCONSIN RECORD

Katherine D. Rill

1520 Bowen Street
Oshkosh, WI 54901

My recent discovery of green spleenwort (*Asplenium viride* Hudson) in Florence County, Wisconsin, adds a second record for the state. The fern grew near the Brule River in crevices and among mosses on shaded, north-facing dolomitic cliffs of the Saunders Formation (fide Gene LaBerge, Univ. of Wisconsin-Oshkosh Geology Dept.). This Florence County population marks a northwest range extension in Wisconsin of approximately 90 miles.


Asplenium viride, a circumboreal species and one of the rarest vascular plants in Wisconsin, was previously known only from Washington Island, Door County [Fuller 56,996, 26 July 1925 MIL (Breakey 1931)]. W. Carl Taylor and Neil Luebke of the Milwaukee Public Museum revisited the Washington Island site in August 1978 and found "about 40 plants growing in crevices of north-facing shaded Niagara limestone outcrops. . . ." (pers. comm., Nov. 1983). In their recent enumeration of the ferns of Wisconsin, Peck and Taylor (1980) give only this single location.

This species is apparently unknown in Minnesota (Tryon 1980) with the next site to the west in the Black Hills of South Dakota. Here it is described as "infrequent in crevices in limestone" (Van Bruggen 1976). With reference to the South Dakota plants, Petrik-Ott (1979) states that it was ". . . collected only from Iron Creek Canyon, Lawrence County, S.D., growing in moist well shaded limestone rock crevices above Iron Creek." According to Billington (1952), the fern has been collected in Michigan in Chippewa County on limestone cliffs of the Niagara escarpment. The earliest Michigan collection was made by N. C. Fassett at Pickford (Fassett, 14,742). This specimen is in the University of Michigan Herbarium.

This attractive small fern is well illustrated in Petrik-Ott (1979), and Billington (1952).

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On the cover: *Carex stricta*
photographed at Long Point, Norfolk Co., Ontario
on 14 June 1980 by P. M. Catling.

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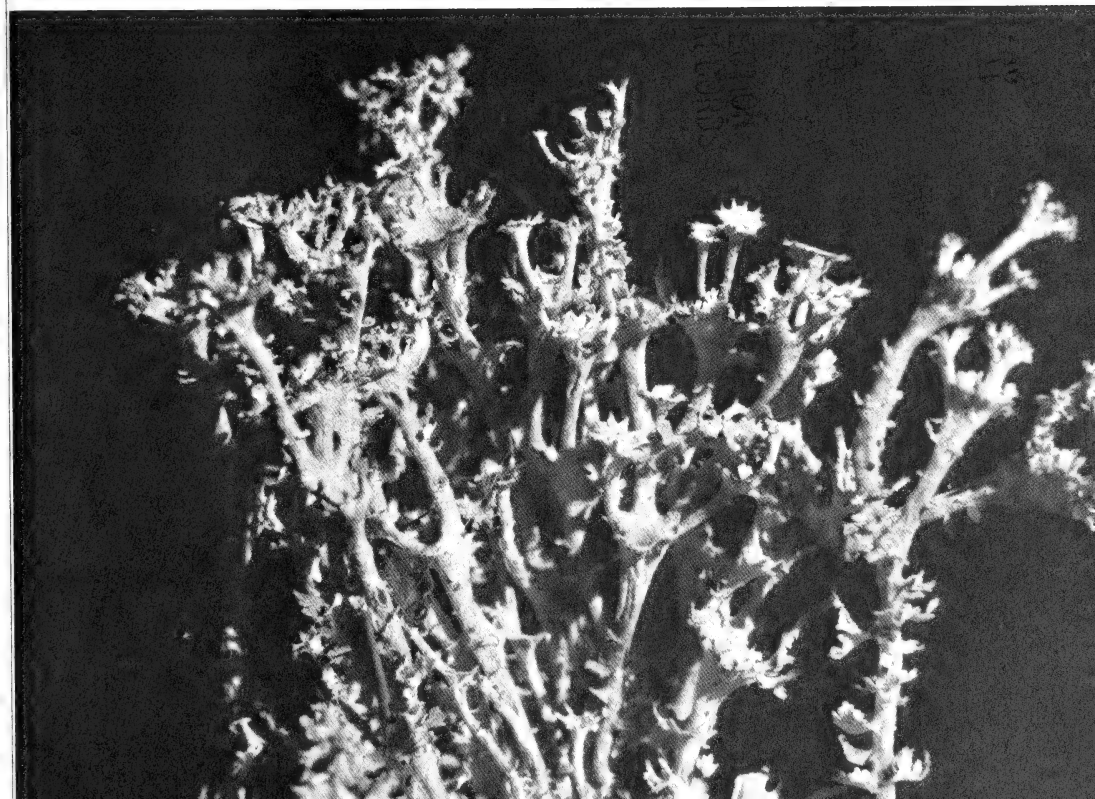
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**WOODLOT COMPOSITION AND SUCCESSIONAL TRENDS
IN
SOUTH-CENTRAL LOWER MICHIGAN**

Sheridan L. Dodge and Jay R. Harman

Department of Geography
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Two distinctly different forest associations, both widespread in the eastern United States, share dominance of uplands in the southern Lower Peninsula of Michigan. Oak-hickory forests occupy well-drained sites and are part of a larger area that extends eastward from northwest Indiana through the Lower Peninsula and into Ontario. Sugar maple-beech (*Acer saccharum* Marsh.-*Fagus grandifolia* Ehrh.) forests characterize somewhat more mesic sites in the same area (Braun, 1950). Although the border between the two forest associations is generally poorly defined (Braun, 1950; Vankat, 1979), a rather distinct boundary between sugar maple-beech and oak-hickory forests is locally discernible in south-central lower Michigan—an area delineated as transition by Veatch (1959) and Kuchler (1964).

Despite the development and persistence of these distinct, contiguous forest communities within the region, no systematic inventory of their composition has been published. Most previous studies of composition have been confined to single stands or relatively small areas (State of Michigan, Department of Conservation, 1941; Schneider, 1963, 1966; Beaman, 1970; Frye, 1977; Beach and Stevens, 1980). But even in more extensive investigations, the description of vegetation is general and non-quantitative (Veatch, 1959). Moreover, Veatch's study (1959) is the only characterization of presettlement vegetation in this area of the state and his map is not always an accurate delineation of forest types (Dodge, 1984).

Not only have these forest communities not been described in detail, successional trends within them are uncertain. Whitford (1907) and Quick (1953) contended that, given an unchanging climate and continuing adjustments of species' distributions through time, sugar maple-beech forests will eventually dominate most uplands in the Lower Peninsula. The emergence of this climax seems uncertain, however, because of the juxtaposition of apparently stable examples of both sugar maple-beech and oak-hickory stands in other areas nearby (Friesner and Potzger, 1934; Charton, 1972). The presence of such dissimilar upland forest communities within the south-central Lower Peninsula creates an opportunity for the investigation of the successional question in the oak-hickory association.

The primary objectives of our investigation are to derive a qualitative and quantitative description of the composition of both the oak-hickory and sugar maple-beech associations in this region. Second, we will attempt to ascertain whether the modern species makeup of these forest types is sub-

stantially different from upland forest composition at the time of pioneer settlement. Third, we will examine the problematic future composition of the regional oak-hickory association; namely, is there an apparent successional trend in this community?

PHYSICAL SETTING

Geomorphology and Soils

The area of study encompasses the northeastern townships of Ingham County (Meridian, Williamston, and Locke), the northern tiers of sections in Alaiden, Wheatfield, and Leroy Townships (Figure 1), and some sections of Bath, Shaftsbury, and Perry Townships in Clinton and Shiawassee Counties. Throughout this region, numerous wooded areas typical of both forest associations occur. Total area of the study tract is approximately 533 km² or about 52,480 ha.

The regional landscape has been largely influenced by Wisconsin glacialiation with moraine, till plain (or ground moraine), and meltwater channel outwash the principal glacial features (Martin, 1955). Topography associated with till plain has typical relief of 6–12 m and slopes of 2–6 percent. However, northern sections of the area, characterized by a complex morainic system, have greater relief, 15–21 m, and steeper slopes of 18–30 percent. Glacial sediments that underlie the region are primarily sandy and bouldery tills associated with the Saginaw Lobe (Wayne and Zumbredge, 1965). Limited areas of valley outwash, located along the channel of the Red Cedar River and its northern tributaries, are underlain by thin sand and silt deposits (Vanlier et al., 1969).

Soils are extremely varied because of the complex nature of the parent material as well as genetic, lithologic, and stratigraphic differences between solum and substratum and because of the many different glacial landforms in the area (Veatch et al., 1941). Well-drained and somewhat poorly-drained soils within the region are Alfisols and most are Typic Hapludalfs. Poorly and very-poorly drained soils are very diverse in their taxonomic classification, with Alfisols, Mollisols, Inceptisols, Entisols, and Histisols all represented in this group of wetter soils.

Vegetation

The presettlement upland forest of this area consisted of three major associations: oak, oak-hickory, and sugar maple-beech (Veatch, 1959). According to Veatch (1959), oak forest was dominated by black oak (*Quercus velutina* Lam.), although red oak (*Q. rubra* L.) and white oak (*Q. alba* L.) were common. Oak-hickory forests were dominated by these oak species plus a number of hickory species. The mesic association, sugar maple-beech, was characterized not only by these two species, but also by lesser amounts of oaks and hickories, elm (*Ulmus* spp.), basswood (*Tilia americana* L.), and ash (*Fraxinus americana* L.). Moreover, the occurrence of sugar maple-beech and oak-hickory stands was site specific and to some extent geographically restricted. Uplands north of the Red Cedar River were forested primarily by a mixed oak-hickory association with inclusions of oak woods. On uplands south of the Red Cedar River, sugar maple and beech were predominant, whereas the eastern portion of the study tract and margins of Red Cedar tributaries were dominated by lowland hardwoods. Chandler Marsh north of East Lansing was also an area of swamp hardwoods and probably tamarack (*Larix laricina* K. Koch) (Veatch, 1959).

Due to extensive forest destruction, only "about 15 percent [of Ingham county] remains in forest similar to the original cover" (Veatch et al., 1941) and nearly all is "second-growth" (Beal, 1902; Dice, 1931; State of Michigan, Department of Conservation, 1941; Beaman, 1970; Flanders, 1971; Frye, 1977; Beach and Stevens, 1980). Most of the remnants of the once extensive presettlement forest are relatively small woodlots. Of these stands, Toumey Woods on the Michigan State University campus is an example of one that is not greatly altered from its original state (Schneider, 1963, 1966; Flanders, 1971).

The primary overstory species in woodlots on the Michigan State campus is sugar maple (Table 1). Beech, although much less important than sugar maple, is nearly twice as dominant as white ash, red oak, or basswood. However, the species mix and dominance vary within individual stand because of different site conditions and history.

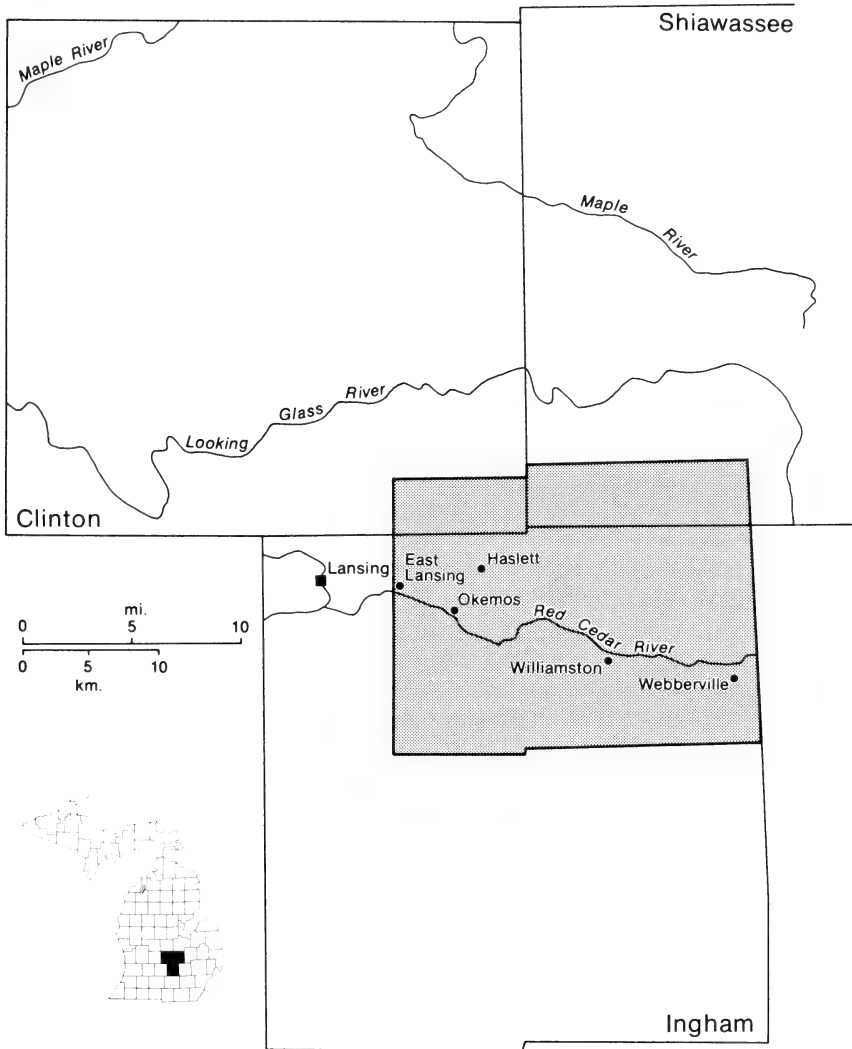


Figure 1. Location of study area.

Black oak was the primary canopy species (Table 2) in a number of oak-hickory stands surveyed elsewhere in the study region (State of Michigan, Department of Conservation, 1941). The combined percentage of all oaks was somewhat greater than the total for hickory (49.5 vs. 46.2). Beech was noted (3.0 percent) in only one of the four oak-hickory stands and sugar maple was not found in any sampled plots within these woods.

METHODS

Woodlot Selection

A sample of twenty-four woodlots was selected to represent each of the two regional upland forest associations. Only those sugar maple-beech and oak-hickory stands with lesser

TABLE 1. Relative dominance of selected tree species in four Michigan State University woodlots [expressed as percent] (Beach and Stevens, 1980).

	Baker	Sanford	Toumey	Sandhill	Mean
<i>Acer saccharum</i>	32.0	28.0	60.8	38.0	39.7
<i>Fagus grandifolia</i>	7.1	21.8	6.0	18.3	13.1
<i>Tilia americana</i>	11.5	3.4	2.9	11.9	7.4
<i>Quercus rubra</i>	14.9	4.3	4.9	5.2	7.3
<i>Fraxinus americana</i>	10.0	4.8	3.8	2.4	5.3

TABLE 2. Selected woodlot composition at Rose Lake Wildlife Research Station [expressed as percent of woodlot by species; individuals > 76m dbh] (State of Michigan, Department of Conservation, 1941).

	No. 2	No. 3	No. 5	No. 6	Mean
<i>Quercus velutina</i>	10	50	20	34	28.5
<i>Carya glabra</i>	45	3	40	12	25.0
<i>Carya ovata</i>	25	35	12	13	21.2
<i>Quercus alba</i>	15	15	10	14	13.5
<i>Quercus rubra</i>	4	2	1	23	7.5

relative amounts of apparent disturbance were chosen in order to facilitate both the comparison of modern with presettlement composition and the assessment of possible successional trends. Woods that were severely cut-over or where the second-growth canopy was dominated by disturbance indicators such as black cherry (*Prunus serotina* Ehrh.), red maple (*Acer rubrum* L.), or bigtooth aspen (*Populus grandidentata* Michx.) were not used as study sites. The sample included only woods situated on higher topography as determined from site depiction on topographic maps, soil series and drainage class, and visual inspection of woodlot topography and composition. For example, assemblages of such species as elm (*Ulmus americana* L.), red maple, silver maple (*Acer saccharinum* L.), cottonwood (*Populus deltoides* Bartr. ex Marsh.), and swamp white oak (*Quercus bicolor* Willd.) are suggestive of wet soil conditions; therefore, we did not include such stands in the study. In addition, we tried to select woodlots with area greater than approximately 2 ha (5 acres) in order to minimize the effects of "edge", a condition in which border vegetation differs significantly from the less disturbed woodlot interior (Gysel, 1951).

Woodlot Sampling

The study woodlots were sampled by the point-quarter (quadrant) method. Quadrant points, species, diameter (>7.5 cm), and point-plant distance were selected and recorded in the usual prescribed manner (Brower and Zar, 1977). The number of sampled points ranged from 8 in smaller stands to 24 in larger woodlots, although the number of cases in the lower range was few. This number varied between woodlots because of the need to avoid wet or highly disturbed areas and to prevent quadrant overlap. Stands with a relatively homogeneous canopy, as is the case in many sugar maple-beech woods, also were sampled with fewer points.

The sapling layers (≤ 7.5 cm diameter; ≥ 1 m high) of the woodlots were also examined using the same quadrants established in the overstory sample. All oak-hickory stands were surveyed in this manner and, for comparison, we recorded reproduction data from one sugar maple-beech woodlot. The decision to sample only one mesic woods was based on the known uniformity of reproduction under the regional sugar maple-beech canopy (Schneider, 1963, 1966; Rogers, 1978). Furthermore, examination of our sample sugar maple-beech woodlots confirmed their observations.

Archival Search

We also conducted an examination of the Land Office Survey notes of 1826 and 1827 in order to determine the probable presettlement species composition of the sampled woodlots. No attempt was made to collect all possible data for a comprehensive reconstruction of the original forest cover. Rather, we identified all study stands situated on original survey lines and recorded the species of the "witness", or marker, trees that were once located on these bordering transects. If no witness tree was noted on the traverse bounding the present site of a woodlot, we recorded the species of the tree nearest that woodlot.

Data Processing

Importance values (IV) for all tree species (>7.5 cm diameter) in each woodlot were calculated from the data collected during the point-quarter surveys (Brower and Zar, 1977). From these individual species IV's, we then calculated the mean importance value for each observed species in either the oak-hickory or sugar maple-beech woodlot sample.

Species presence data obtained in the sample of woodlot reproduction were converted to species frequencies, or the probability of finding a given species within a woodlot (Brower and Zar, 1977). These frequencies were also averaged for the oak-hickory woodlot group in order to describe the composition of the reproduction layer of these woods.

RESULTS

Modern Composition

The overstory species composition of sampled woodlots generally corresponds to the traditional oak-hickory and sugar maple-beech labels, although the presence of significant amounts of red maple and black cherry in the former association is worthy of note (Table 3). These two species have larger importance values than the summed measures of all hickory species (0.266). Species such as sugar maple, beech, basswood, and bitternut hickory (*Carya cordiformis* (Wangenh.) K. Koch) which are normally associated with mesic conditions were seldom found with the drier site oaks and hickories. Conversely, sugar maple is clearly the forest dominant in sampled mesic woodlots (Table 4). Beech is less dominant but still much more important than any of the remaining canopy species. Black oak, pignut hickory [*Carya glabra* (Mill.) Sweet], and shagbark hickory [*C. ovata* (Mill.) K. Koch], so characteristic of oak-hickory woods, have very low importance values in regional mesic woodlots.

TABLE 3. Mean importance values of oak-hickory woodlots.

Species	IV	Species	IV
<i>Quercus velutina</i>	.809	<i>Ostrya virginiana</i>	.015
<i>Quercus alba</i>	.680	<i>Fagus grandifolia</i>	.010
<i>Acer rubrum</i>	.504	<i>Ulmus rubra</i>	.009
<i>Prunus serotina</i>	.289	<i>Ulmus americana</i>	.008
<i>Carya glabra</i>	.229	<i>Cornus florida</i>	.007
<i>Quercus rubra</i>	.221	<i>Crataegus</i> sp.	.005
<i>Sassafras albidum</i>	.073	<i>Tilia americana</i>	.004
<i>Fraxinus americana</i>	.034	<i>Carya cordiformis</i>	.004
<i>Carya ovata</i>	.033	<i>Liriodendron tulipifera</i>	.002
<i>Amelanchier</i> sp.	.024	<i>Celtis occidentalis</i>	.002
<i>Acer saccharum</i>	.019	<i>Morus alba</i>	.001
<i>Populus grandidentata</i>	.017		

TABLE 4. Mean importance values of sugar maple-beech woodlots.

Species	IV	Species	IV
<i>Acer saccharum</i>	1.197	<i>Quercus alba</i>	.027
<i>Fagus grandifolia</i>	.627	<i>Carpinus caroliniana</i>	.012
<i>Fraxinus americana</i>	.262	<i>Quercus velutina</i>	.008
<i>Tilia americana</i>	.240	<i>Liriodendron tulipifera</i>	.007
<i>Ostrya virginiana</i>	.128	<i>Amelanchier</i> sp.	.006
<i>Prunus serotina</i>	.126	<i>Quercus muehlenbergii</i>	.006
<i>Quercus rubra</i>	.112	<i>Carya glabra</i>	.003
<i>Carya cordiformis</i>	.073	<i>Crataegus</i> sp.	.002
<i>Acer rubrum</i>	.063	<i>Quercus macrocarpa</i>	.002
<i>Ulmus americana</i>	.049	<i>Carya ovata</i>	.001
<i>Ulmus rubra</i>	.043	<i>Cornus florida</i>	.0001

Reproduction within oak-hickory stands is markedly different from the species composition of the canopy (Table 5). Black cherry and red maple are by far the most common species of the seedling/sapling layer, whereas oaks and hickories are relatively infrequent, having a total mean frequency of only 0.124. Juvenile beech and sugar maple are also uncommon in oak-hickory woods (0.033 total mean frequency). However, just the opposite is true in a typical sugar maple-beech woodlot (Table 6) where reproduction is almost entirely sugar maple.

Presettlement Composition

Only one-quarter of the woodlots studied have boundaries that coincide with locations of recorded witness trees, but in each of these cases presettlement species are similar to those observed in the modern stand composition (Table 7). In addition, species of witness trees formerly located near present woodlot sites are also very similar to species that now dominate study woods. Despite the small woodlot sample and relatively few witness trees, no stands appear to have experienced marked changes in canopy composition during the past 150 years.

DISCUSSION

Present Composition

Although the label "sugar maple-beech" is an accurate description of regional mesic stands, the term "oak-hickory" is less applicable to the present upland xeric community within the area. There are variations of composition among the woodlots we examined, but the high average importance of red maple and black cherry is notable within nearly all xeric woods. The importance value (.504) of red maple is exceeded only by black and white oak and is nearly two times greater than that of pignut hickory and red oak. This situation is consistent with findings reported elsewhere for southern Michigan (Gysel and Arend, 1953) and southern Wisconsin (Lar-

TABLE 5. Mean frequencies of reproduction in oak-hickory woodlots.

Species	Frequency	Species	Frequency
<i>Prunus serotina</i>	.70	<i>Quercus rubra</i>	.02
<i>Acer rubrum</i>	.47	<i>Carpinus caroliniana</i>	.02
<i>Amelanchier</i> sp.	.24	<i>Acer negundo</i>	.01
<i>Fraxinus americana</i>	.18	<i>Populus grandidentata</i>	.01
<i>Ulmus americana</i>	.11	<i>Tilia americana</i>	.01
<i>Ulmus rubra</i>	.10	<i>Cornus alternifolia</i>	.01
<i>Sassafras albidum</i>	.09	<i>Carya cordiformis</i>	.01
<i>Crataegus</i> sp.	.07	<i>Celtis occidentalis</i>	.01
<i>Ostrya virginiana</i>	.06	<i>Quercus velutina</i>	.004
<i>Cornus florida</i>	.05	<i>Prunus virginiana</i>	.003
<i>Quercus alba</i>	.05	<i>Malus</i> sp.	.003
<i>Carya glabra</i>	.04	<i>Fagus grandiflora</i>	.003
<i>Acer saccharum</i>	.03	<i>Morus alba</i>	.002

TABLE 6. Frequencies of reproduction - Woodlot 1 (n of points = 20).

<i>Acer saccharum</i>	1.00
<i>Fagus grandiflora</i>	.10
<i>Ostrya virginiana</i>	.05
<i>Ulmus rubra</i>	.05

son, 1953; Peet and Loucks, 1977). Locally, neither red maple nor black cherry appears to have been a frequent member of the presettlement forest because the original surveyors made little reference to them. Parmelee (1953), however, expressed uncertainty about this issue, primarily because of Beal's (1902) observation that red maple was common in the oak stands then situated on the site of Michigan State University.

Possible reasons for the ascendancy of red maple and black cherry are numerous and complex. Oak reproduction is often sparse while red maple and black cherry are prolific reproducers. Because of this, certain types of disturbances may favor red maple and cherry reproduction, especially during periods of drought, and in more open, disturbed stands the reproduction of relatively shade-intolerant cherry is enhanced. In addition, selective cutting for firewood or structural timber may also favor black cherry and red maple because they are less valuable for these purposes. Locally, oaks are often relegated to drier locations while red maple and black cherry dominate somewhat more moist areas that are probably former oak sites (Fowells, 1965; Gysel, 1956; Gysel and Arends, 1953; Harlow et al., 1979; Westveld, 1949). Finally, Parmelee (1953) suggested that the trend to an increased dominance of red maple and black cherry may not be a product so much of disturbance but, rather, is representative of a long-term fluctuation of species importance about a midpoint that represents an optimal climax.

We agree with other interpretations that the conspicuous presence of red

TABLE 7. Presettlement composition of study woodlots (more than one individual noted in parentheses).

Woodlot No.	Woodlot Type	Witness Trees	Woodlot No.	Woodlot Type	Witness Trees
1	SM-B	beech (2)	26	O-H	black oak
		white ash			
5	SM-B	beech (2)	27	O-H	white oak (3)
7	SM-B	beech (2)	28	O-H	black oak
		white ash			
		ironwood	30	O-H	white oak
					white ash
9	SM-B	beech (2)	31	O-H	white oak (3)
13	SM-B	beech	34	O-H	white oak (3)
		ironwood			
16	SM-B	beech	35	O-H	black oak
					white oak
17	SM-B	beech			
		white ash	37	O-H	white oak
19	SM-B	beech	38	O-H	black oak
		sugar maple			
		ironwood	41	O-H	black oak (2)
20	SM-B	sugar maple (2)	47	O-H	black oak
		basswood			bigtooth aspen
22	SM-B	beech	48	O-H	black oak
		sugar maple			
		red maple			
		elm			
23	SM-B	beech (2)			
		sugar maple			

maple and black cherry in both the canopy and reproduction layer of our woodlots is at least partially a product of past disturbances. For example, use of oak-hickory woods for grazing, as noted by Westveld (1949), leads to fruit destruction and the establishment of species with abundant seed production and low to moderate shade-tolerance. Such long-term use and repeated good seed years would allow red maple to become a highly successful successional species, particularly in submesic oak woods. On such sites, red maple seedlings and saplings develop deep initial tap roots, a characteristic unusual in red maples located in more moist areas (Fowells, 1965; Toumey and Korstain, 1947). Again we note that repeated cutting of regional woodlots has also altered the species composition. Good examples of this are two non-study stands (NW 1/4, SE 1/4, Sec. 24, T4N, R1W and NE 1/4, SE 1/4, Sec. 24, T4N, R1E) where oak removal has resulted in dominance by red maple.

In addition to these disturbances, fire plays a role in determining the importance of red maple and black cherry and may be instrumental in the trends we observed. Stems of both species are readily injured by burning. Although very hot fires will kill individuals of these species, frequent cooler fires induce vigorous root sprouting (Fowells, 1965) which may increase the importance of red maple and black cherry in the long term. Like Parmelee

(1953), we found little evidence of fire in the original survey records of Ingham County, but we speculate that fires were sufficiently common in the presettlement forest to maintain a relatively unimportant role for both species. The apparent increase of red maple and black cherry then may be partially explained by a reduction in the frequency or intensity of wildfires in relatively recent times. Also, the regional landscape has been transformed during the last century into a patchwork of woodlots and agricultural land that may not favor free-running fires as easily as might a continuously forested landscape.

In summary, the xeric woods of the region might more properly be described by terms other than "oak" or "oak-hickory". Eyre (1980) designated forests of this part of the middle west as the "White Oak-Black Oak-Northern Red Oak" cover type where hickory usually comprises less than ten percent of the stand. Red oak is not a codominant, on average, within the woodlots we surveyed and a local type for this part of Michigan would more accurately be described as "Black Oak-White Oak-Red Maple". It is a non-traditional but more appropriate title given the composition of the woodlots in the south-central Lower Peninsula.

Successional Trends

The present distribution of sugar maple-beech and oak-hickory woodlots generally corresponds to the patterns in upland forest data recorded by the Land Office Survey of 1826-27. South of the Red Cedar River, the surveyors observed "rolling sugar", "1st rate", and "good" land dominated by such species as "sugar" (sugar maple), beech, "linden" or "lyme" (basswood), ash, and elm. These species presently characterize the same area. North of the river in the central section of the study region now characterized by oak-hickory stands, the survey described the land as "rolling oak" and "2nd rate" (settlers believed that oak forests were indicative of soils less fertile than soils that supported forests of sugar maple and beech). In this area, the surveyors recorded many different oaks (white, black, red, and "yellow") as well as hickories, and infrequent beech. Although, as previously noted, they rarely registered red maple or black cherry witness trees, the general agreement between past and present composition within our study suggests there has not been any profound local successional change within the forest associations we examined.

In one part of our study area, the composition at first examination might suggest classical succession from oak-hickory to sugar maple-beech. In Locke Township and as far north as Perry in southern Shiawassee County, land survey records indicate that this entire area was a mosaic of both sugar maple-beech and oak-hickory stands intermixed with lowland hardwoods and tamarack swamps. Today, however, upland woodlots in this region are mainly sugar maple-beech. Rather than interpret these as former oak-hickory stands, we speculate that most oak-hickory woods have been cleared for agricultural land or structural timber. Furthermore, we conclude that the scattered sugar maple-beech woodlots are remnants left because they likely served as "sugar bushes". Such maple woods were known sources of maple

sugar, an important sweetener of the period [see Malik (1960)]. We do not interpret the presence of these mesic woodlots as evidence of succession for the following reasons:

1. Reproduction of sugar maple, beech, and bitternut hickory is infrequent in oak-hickory woodlots.
2. Scattered variously-aged concentrations of sugar maple and beech in oak-hickory woodlots are restricted primarily to north-facing slopes. We assume these are compensated sites, i.e., sites that are cooler, with less evaporation and more available moisture. Thus, these occurrences seem to be unlikely precursors of a widespread mesic trend.
3. Moreover, an examination of the Land Office Survey notes reveals that the composition of the understory of the primeval oak forest was remarkably similar to that of the overstory (white oak and black oak) at that time.

What of the future? It appears that the importance of red maple in the overstory will continue to increase as indicated by reproduction layer frequencies. But whether enough of the remarkable number of black cherry seedlings and saplings survive to ensure canopy codominance is problematic. Grazing of woodlots is no longer common and a lessening of this practice may result ultimately in an increased importance of red maple, oaks, and hickories, species with higher shade-tolerances than black cherry (Spurr and Barnes, 1980). Nevertheless, continued cutting of woodlots, especially with disregard of sound silvicultural practices, could continue to favor black cherry. Meanwhile, sustained poor reproduction of both black and white oak may lead to a decline in their canopy importance despite the usual longevity of mature individuals.

SUMMARY AND CONCLUSION

Three important results emerged from this study. First, little historical evidence of conversion of oak-hickory stands to sugar maple-beech stands was found. Sugar maple-beech and oak-hickory forest remnants occur today in much the same portions of the study area where they were described over 150 years ago. Second, little evidence was found within oak-hickory stands to suggest they are presently undergoing a conversion to sugar maple-beech. Sugar maple, beech, and other mesic associates are uncommon in oak-hickory stands and usually geographically restricted to what appear to be compensated sites. Third, compositional change, probably resulting from recent human impact, is particularly evident in oak-hickory woodlots; less such evidence was found in sugar maple-beech woods. These changes center on the increased importance of red maple and black cherry, species probably of lesser importance in all but the most open presettlement stands because of their limited tolerance. We conclude that human intervention, either through cutting, livestock grazing, or alterations in natural fire frequency, is the most important agent of change in local woodlots today. Such intervention may be generating a forest composition on former oak-hickory sites that had no widespread analogue in the primeval forest.

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NET PRIMARY PRODUCTION IN A MARSH*

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A first step in understanding the function and structure of ecosystems is measurement of primary productivity, because productivity data integrate the performance of the whole system as a quantitative starting point for investigation. Primary productivity is the rate at which photosynthesis binds energy and creates organic matter per unit area per unit time. Net primary production (NPP) is the amount remaining after respiratory use by the plants and is the source of food used by all heterotrophic organisms.

The purpose of this study was to measure net primary productivity of the emergent vegetation of the zone bordering a southeastern Michigan marsh ecosystem and to investigate its relationship to solar radiation, water temperature, and water level. The research was performed in the marsh on Swift Run, a stream located in section 10, T3S, R6E, Washtenaw Co. The wetland near the I-94 expressway and Platt Road is approximately 3 ha in area, at an elevation 250 m (42°14'N, 83°42'W). The marsh is part of the county storm drain system and acts as a storm water retention basin absorbing floodwaters and the materials they carry from the watershed above the marsh.

METHODS

To estimate net primary production (NPP), measurements of the above- and belowground standing crop of marsh vegetation were made during the 1982 growing season. NPP was determined by harvesting green shoots at monthly intervals from May through October (Malone, 1961). No correction was made for litter fall (mortality) and seed production between sampling periods. The vegetation was sampled by circular 0.25 m² quadrats along transects. Three quadrats (at water edge, middle, and land edge areas of the littoral zone) were clipped on each sampling date on both the south and north sides of the marsh. Shoots clipped above the base of the swollen rhizomatous tissue were sorted into three groups: *Typha*, *Sparganium eurycarpum*, and infrequent species grouped as other species. *Typha latifolia* and *T. angustifolia* were grouped as *Typha* because I could not identify the species during their early development and because so many morphological variations occur between them in the Swift Run marsh.

Belowground biomass was sampled three times during the growing season with the same methods used for the aboveground method. After litter was removed, belowground materials were obtained by excavation along the edges of the quadrat to a depth of 30 cm. The roots and rhizomes inside the quadrat were placed in a 0.5–1 cm size net and sprayed with water from a high-pressure hose to remove soil. No attempt was made to sort belowground biomass into taxonomic groups or living and dead parts due to the difficulty in making such determinations. Aboveground (green shoots) and belowground (roots and rhizomes) plant materials were dried at 105°C for 24 hours or until a constant weight was obtained. Biomass determination was made

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using a Mettler p3 balance, sensitive to 1 g. Data are reported by the mean grams dry weight per m².

To study the relationship between NPP and environmental factors, solar radiation, water temperature, and water level were measured on each sampling date. Solar radiation in watt/m² was measured with the LI-COR 185 Quantum/Radiometer/Photometer and LI-Cor 200s pyranometer sensor at noon of each sampling day. If sampling days were cloudy, solar radiation was measured on the next clear day. Water level was measured from a stage marker located in the middle of the littoral zone. For determining water temperature, a thermometer was used at noon of each sampling day.

Simple linear and multiple linear correlations were calculated with the environmental factors described above as independent variables. Dependent variables used were community biomass, daily community productivity, and biomass and daily productivity of the two dominant species groups: *Typha* and *S. eurycarpum*. Regression equations were calculated for those relationships with statistically significant correlation coefficients. For correlation with productivity, environmental factors were transformed in two ways. Average values were found by summing two consecutive monthly values and dividing by 2. Change in factors was found by subtracting consecutive monthly values. The correlation coefficients of productivity and biomass (dependent variables) with the combination of environmental factors (independent variables) were calculated by using multiple linear regression of Eastern Michigan University Statpack (an integrated, interactive statistical package written for terminal use).

RESULTS AND DISCUSSION

Aboveground biomass values (g/m²) of *Typha*, *Sparganium eurycarpum*, and other species were greatest on August 8 (Table 1). The individual groups reached maximum standing crop on August 8 (*Typha*); September 12 (*S. eurycarpum*); and June 10 (other species). The estimate of net primary production obtained by summing the species peaks (1597 g/m²) is within the confidence interval of the community estimate (1388 g/m² ± 491.22). There is a discrepancy of 209 g between the estimate of production based on the community value and that based on the sum of individual species peaks because the dominant producers (*Typha* and *S. eurycarpum*) reached their peak standing crop one month apart. This research supports the suggestion of Malone (1968) that summing the species peaks is useful for measurements of production in mixed herbaceous communities, while the community standing crop at one moment will underestimate production in such communities, but is useful for homogeneous habitats. Community peak productivity occurred between July 18 and August 8 at the rate

TABLE 1. Aboveground biomass (g/m²). An asterisk indicates the data of the peak standing crop.

	Total Community	<i>Typha</i>	<i>Sparganium eurycarpum</i>	Other species
May 11	29	11	11	0
June 10	408	161	235	12
July 18	892	548	332	13
Aug. 8	1388*	976*	412	1
Sept. 12	1104	492	608*	4
Oct. 11	800	513	287	8

of 23.6 g/m²/day (Table 2). Peak productivity occurred between July 18 and August 8 for *Typha* (20.4 g/m²/day) and between May 11 and June 10 for *S. eurycarpum* (7.2 g/m²/day). For the other species maximum productivity occurred during the early growing season (May 11–June 10) and decreased after the two dominant species had high productivity.

Relatively less biomass was found in belowground components at the peak of the growing season (ratio of about 2:1 during July and August) (Table 3) than late in the growing season (ratio of 3.3:1 during October), even though the standing crop in the season was less than that at the peak. The belowground maximum standing crop (2832 g/m²) was found on July 2 among the three sampling days. Belowground biomass accounted for 70% of the total biomass of mixed stands on July 2, 66% on August 8, and 76% on October 11. Figure 1 shows seasonal patterns of aboveground/belowground biomass emphasizing the significantly greater mean belowground than aboveground biomass.

Environmental factors are shown in Table 4. Solar radiation ranged from 705 to 1101 watts/m², water temperature from 12 to 27°C, and water level from 0 to 14.5 cm. There was no great variation of water level except on September 12. At that time there was no surface water at the stage marker though surface water remained in the marsh. Solar radiation and water temperature had a small deviation throughout the growing season compared with water level.

Biomass was not significantly correlated with solar radiation, water temperature, and water level. Among the correlation coefficients of productivity (total community, *Typha*, and *Sparganium*) on the transformed environmental factors, only three correlations were significant: total productivity on the average water level ($P < 0.05$, $r = 0.9128$) and on the water level change ($P < 0.05$, $r = -0.9267$) and *Sparganium* productivity on the water temperature change ($P < 0.01$, $r = -0.9622$). Only productivity of *S. eurycarpum* was significantly correlated with multiple environmental factors. With three independent variables (solar radiation change, water temperature change, and water level change) and one dependent variable (*Sparganium* productivity), the squared multiple correlation coefficient (R^2) is 0.9803 ($P < 0.01$). The correlation coefficients of productivity on all environmental factors indicate higher values, while biomass indicate lower figures except the correlation of *S. eurycarpum* on water level and on solar radiation,

TABLE 2. Aboveground productivity (g/m²/day). Double asterisks indicate peak productivity.

	Total Community	<i>Typha</i>	<i>Sparganium</i> <i>eurycarpum</i>	Other species
May 11	12.4	5.2		
June 10	12.7	10.2	7.2	0.4**
July 18	23.6**	20.4**	2.6	0
Aug. 8	– 8.1	– 13.6	3.8	– 0.5
Sept. 12	– 1.0		5.6	0.1
Oct. 11		0.7	– 11.1	0.1

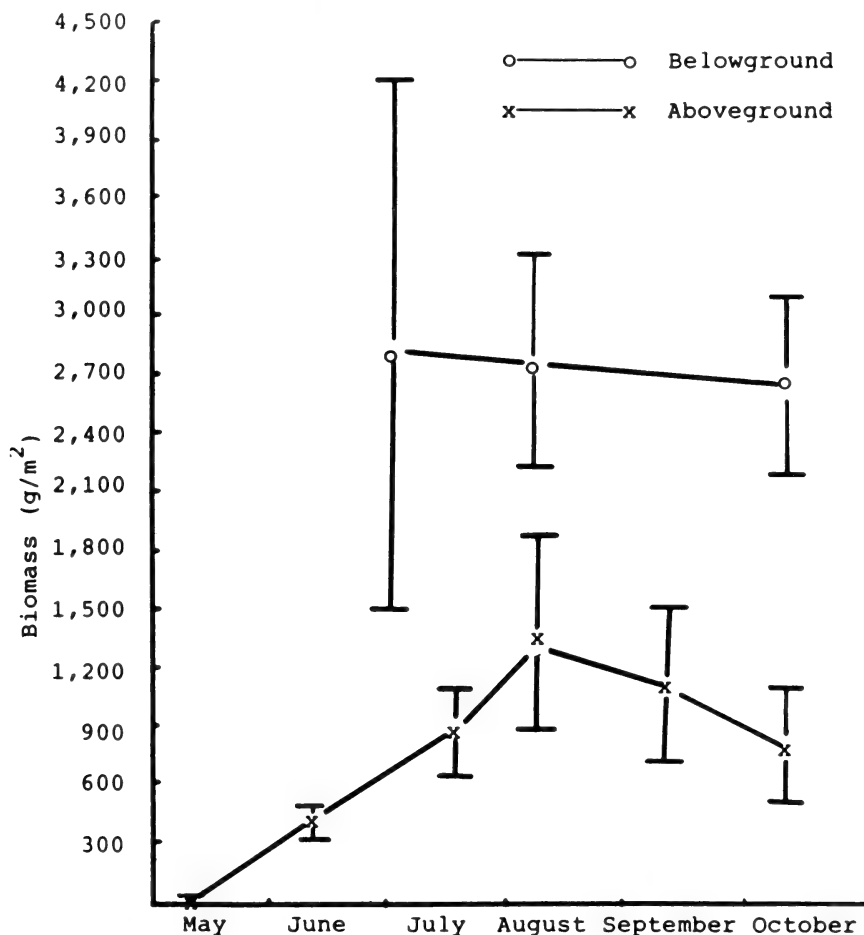


Fig. 1. Comparison of seasonal changes between aboveground and belowground biomass. Vertical bars represent standard error of the mean values. Belowground data represent the mean of three replicated samples, and aboveground data represent the mean of six replicated samples.

TABLE 3. Belowground biomass, ratio of belowground and aboveground biomass, and percentage of belowground over total of three sampling days. Double asterisks indicate peak values.

	Belowground biomass g/m ²	Belowground/ Aboveground Ratio	Belowground/ Total %
July 2	2832 ± 1352.52	2.3	70
Aug. 8	2768 ± 526.87	2.0	66
Oct. 11	2632 ± 442.21	3.3	76

TABLE 4. Solar radiation, water temperature, and water level on each sampling date.

	Sunlight watts/m ²	Water °C	Water level cm
May 11	881	23	14.5
June 10	1101.25	23	12.8
July 18	1101.25	27	14
Aug. 8	1013.15	26	13.2
Sept. 12	792.9	23	0
Oct. 11	704.8	12	13

water temperature, and water level. The coefficients for simple linear correlations of productivity on environmental factor change were negative except for *S. eurycarpum* productivity on the solar radiation change. Productivity on average solar radiation, average water temperature, and average water level all showed positive correlation coefficients.

The aboveground biomass of marsh vegetation in this study was higher than that found by van der Valk & Davis (1978), Bernard & Fitz (1979), Grace & Wetzel (1981), and the mean NPP value of Whigham et al. (1978), but lower than that found by Jervis (1969), Klopatek & Stearns (1978), and Bray (1962). The mean value of the above published data (1358 g/m²) was similar to the peak biomass of this study (1388 g/m²). The lowest biomass recorded (1156 g/m², van der Valk & Davis 1978) and the highest biomass (1688 g/m², Bray 1962) with exception of Grace & Wetzel (1981) (2098 g/m²) was within the 95% confidence interval of the values for Swift Run marsh (1388 g/m² ± 491). Locations do not appear to differ significantly. Net productivity of *Typha* in different sites from New Jersey to Oregon also did not differ significantly (Richardson 1978).

Few studies have included measurements of belowground biomass and productivity. In this study productivity was not measured, but biomass was measured. The belowground biomass of this marsh (2832 g/m² ± 1352) was higher than that (1477 g/m² ± 125) reported by Klopatek & Davis (1978) but was similar to that (2960 g/m²) reported by Bray et al. (1959). Belowground biomass accounted for approximately 66% of the total biomass of the study area (*Typha* and *Sparganium eurycarpum*). This value was much higher than that of 36% for *Typha* reported by Whigham & Simpson (1978). The belowground biomass of this study is 2–3 times as great as the aboveground biomass. This ratio of belowground to aboveground biomass is higher than those of Klopatek & Stearns (1978), Bray et al. (1959), and Bray (1962).

The high ratio of belowground to aboveground biomass may be due to high levels of nutrients brought into Swift Run marsh because the marsh is part of a storm drain system for Washtenaw County. The runoff from roadways, the apartment complex, and agricultural lands increases the concentration of nutrients in the marsh. The soil underlying the open water is muck, which is well decomposed organic material and relatively high in mineral content. Richardson et al. (1976) indicate that high concentration of nutrients from domestic sewage effluents enhances belowground productivity of

narrow-leaved sedges (*Carex* sp.) 4 to 6 times the aboveground productivity. Dolan et al. (1981) found that the belowground biomass (4580 g/m^2) in areas receiving 10.2 cm/wk of effluent was approximately 4 times greater than that (1460 g/m^2) in control areas receiving 3.8 cm/wk of natural freshwater. With input of nutrient-rich waters, as in Swift Run marsh and sewage treatment systems, wetland plants show increase in above and belowground production. However, belowground biomass is more affected than aboveground according to this research and the literature reviewed.

The research in the Swift Run shows the strong relation of productivity to average water level and water level change. Weller (1975) also commented that water levels influence the growth of hybrid and common *Typha* species at a significant level ($P < 0.01$). Germination rates and shoot production generally were inversely related to water depth. However, mean maximum height in the hybrid cattail was directly related to water depth. Jervis (1968) thought that high marsh productivity is a function of the availability of water throughout the growing season.

High negative correlation of productivity to environmental factor changes suggest that environmental fluctuations may lead to a reduction of productivity.

Some indications of differences in species behavior can be seen from the correlation analyses, although all relationships but two were not statistically significant. When productivity was correlated with solar radiation change, the r of *Typha* was negative ($r = -0.5532$) and r of *Sparganium* was positive ($r = 0.4154$) though neither was at significant levels. The r values of *Sparganium* productivity on average solar radiation ($r = 0.7284$) and average water temperature ($r = 0.8402$) are higher than those of *Typha* productivity ($r = 0.6003$, $r = 0.3485$, respectively), while the r of *Sparganium* productivity on average water level ($r = 0.5583$) is lower than that of *Typha* productivity ($r = 0.8004$). These may indicate that the productivity of *Typha* is less affected by solar radiation and water temperature but more closely related to water level than that of *Sparganium*. A high negative correlation coefficient of *S. eurycarpum* productivity with water temperature change ($r = -0.9622$, $P < 0.01$) was shown in the Swift Run. Thus, many differences appear to exist in the way the two dominant species groups respond to environmental factors. However, more data are needed to substantiate these differences since almost no linear correlations are statistically significant.

Multiple rather than simple environmental factors have higher correlations, and all of the multiple linear regressions show positive values even though many of the simple linear regressions show negative values. This finding is probably a statistical artifact; that is, multiple linear regression is obtained by adding each of the simple linear regressions. However, the data support the fact that environmental factors generally can show additive and synergistic interactions.

SUMMARY AND CONCLUSIONS

Net primary productivity of emergent vegetation in Swift Run marsh, southeastern Michigan, was studied during 1982 (May to October) with the harvest method.

Based on monthly biomass samples, estimates of net aboveground production were 1388 g/m²yr for the peak community biomass approach and 1597 g/m²yr for the sum of the species peak biomass approach. The estimates of production closely agreed with studies on similar marshes in Minnesota, Wisconsin, New York, New Jersey, and Iowa.

Peak community biomass occurred on August 8. Peak biomass of species groups occurred as follows: *Typha* (*T. latifolia* and *T. angustifolia*) August 8, *Sparganium eurycarpum* September 12, and other species July 18.

Community belowground biomass, sampled three times during the growing season, averaged about 2700 g/m². The ratio of below to aboveground biomass ranged from 2:1 to 3.3:1, which is higher than in most natural marshes. However, high ratios have been reported for marshes experimentally fertilized in investigations on the use of wetlands for wastewater treatment. Since this marsh receives polluted runoff owing to its function as a retention basin in the county drainage system, it is suggested that increased nutrients cause the higher belowground biomass.

Solar radiation, water temperature, and level were measured monthly along with biomass used to estimate net production. Simple and multiple linear correlation coefficients were calculated for community and species group biomass with environmental factors and for community and species group daily productivity with two transformed measures of environmental factors: average between months and change between months. Only four relationships had statistically significant correlation coefficients: *Sparganium eurycarpum* productivity with water temperature change and with the multiple environmental factors and community productivity with average water level and with change in water level. The community productivity relationships were positive for average water level and negative for change in level. This is generally consistent with literature reports and supports the contention that water level is the most important factor controlling wetland ecosystem processes.

Although the relationships were not statistically significant, the correlation analysis suggests several differences in the ways the dominant species groups respond to environmental factors. *Sparganium eurycarpum* productivity was most closely related to water temperature, and *Typha* productivity was most closely related to water level. Also *Sparganium eurycarpum* was positively related to solar radiation change, while *Typha* was negatively related. These relationships suggest species specific behaviors that are sensing the environment differently.

ACKNOWLEDGMENTS

I would like to acknowledge my debt to my major professor, Dr. Patrick Kangas, who showed unending patience, gave constructive criticism and comments, and skillfully guided my work to its completion. Other members of my committee, Dr. Herbert H. Caswell, Jr. and Dr. Dennis C. Jackson, reviewed the work and made suggestions for its improvement and extension. Dr. Gary Hannan helped identify the plants.

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**LITHOSPERMUM (BORAGINACEAE) IN OHIO,
WITH A NEW TAXONOMIC RANK FOR
LITHOSPERMUM CROCEUM FERNALD**

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Lithospermum (Boraginaceae) is a genus of about 44 species with a world-wide distribution, about 17 species of which occur in North America north of Mexico. Four taxa have been collected in Ohio. Three are indigenous to the state and one is adventive.

The following discussion and accompanying distribution maps of *Lithospermum* in Ohio are based upon specimens housed at the following herbaria: BHO, BGSU, CINC. CLM, CM, DEN, DMNH, F, KE, MICH, MU, NDG, OC, OS, Marietta College, Marietta, Ohio, and Muskingum College, New Concord, Ohio. Geographic information is taken from Fernald (1950) and Gleason & Cronquist (1963). The taxonomic treatment follows that of Johnston (1952, 1954) with a single exception. Johnston subsumed *L. croceum* without rank into *L. caroliniense*. I here consider these two taxa as subspecies. Johnston's interpretation of the genus *Lithospermum* excludes the familiar weedy species *L. arvensis* L. (corn gromwell). This species is best treated as *Buglossoides arvensis* (L.) I. M. Johnston and is so listed in *Flora Europaea* (Valentine & Chater 1972).

Lithospermum latifolium Michx. (Fig. 1)

American gromwell is a robust, leafy perennial to 1 m in height which is widely scattered from New York to Minnesota, south to Tennessee, Arkansas, and Kansas. It grows in a variety of deciduous forest communities. In Ohio it is most frequent in open, second-growth woodlands. Although collected from 18 Ohio counties, *L. latifolium* is not at all common. Populations usually consist of few individuals. Possibly it is merely overlooked by botanists, rather than being truly rare. The small flowers are largely hidden by the leaves and the plant as a whole is nondescript. A Montgomery County report (Schaffner 1932) is not mapped in Fig. 1 as no specimen could be located.

Lithospermum officinale L. (Fig. 1)

European gromwell is the type of the genus *Lithospermum*. It is widely distributed throughout Europe and Great Britain. This tall, leafy perennial is similar to *L. latifolium*, but is distinguished by its spreading hairs and small nutlets. Although occasionally reported from the northeastern and mid-western United States, it does not appear to be naturalized in this region.

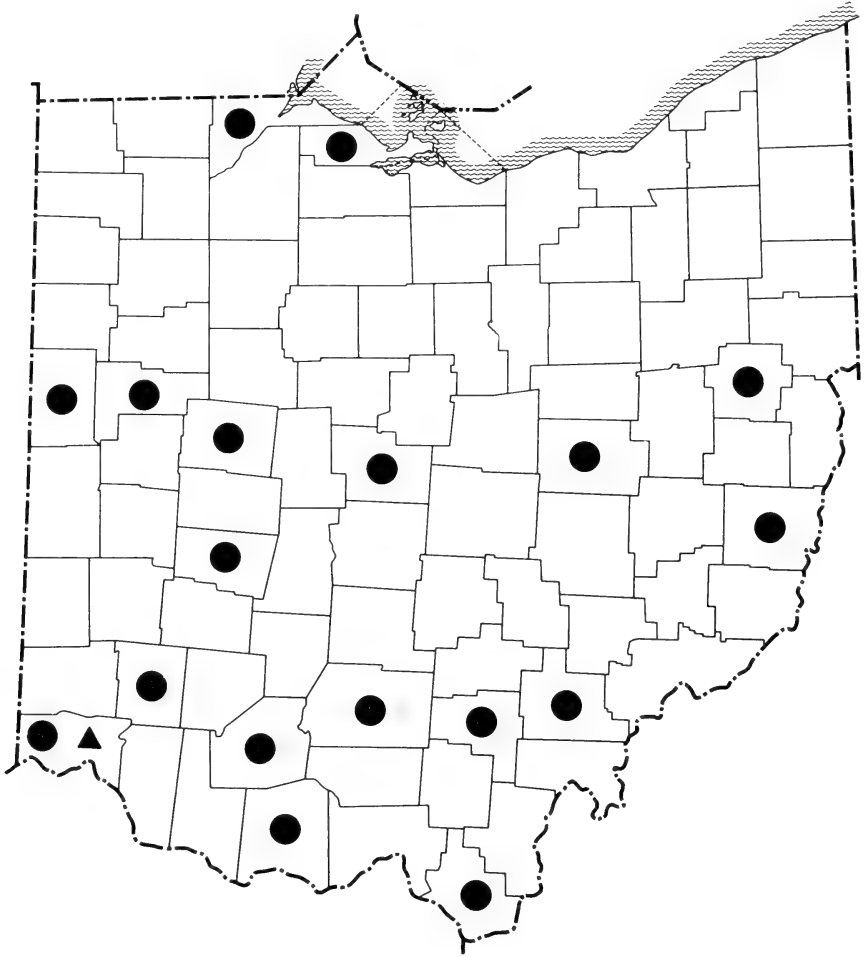


Fig. 1. The Ohio county distribution of *Lithospermum latifolium* (circles) and *Lithospermum officinale* (triangle).

Newberry (1859) indicated that European gromwell occurs in central Ohio, a statement repeated by Kellerman & Werner (1893). However, the only Ohio specimen seen is Cincinnati, Hamilton County, *O. T. Wilson s.n.*, 28 May 1924, OS 32751. This collection is mapped as a triangle in Fig. 1.

Lithospermum canescens (Michx.) Lehm. (Fig. 2)

This species and the next are popularly known as puccoons. The term “puccoon” refers to plants from which dyes were obtained by native Americans and early European settlers. The name does not apply exclusively to *Lithospermum*. The common bloodroot (*Sanguinaria canadensis* L.) is also

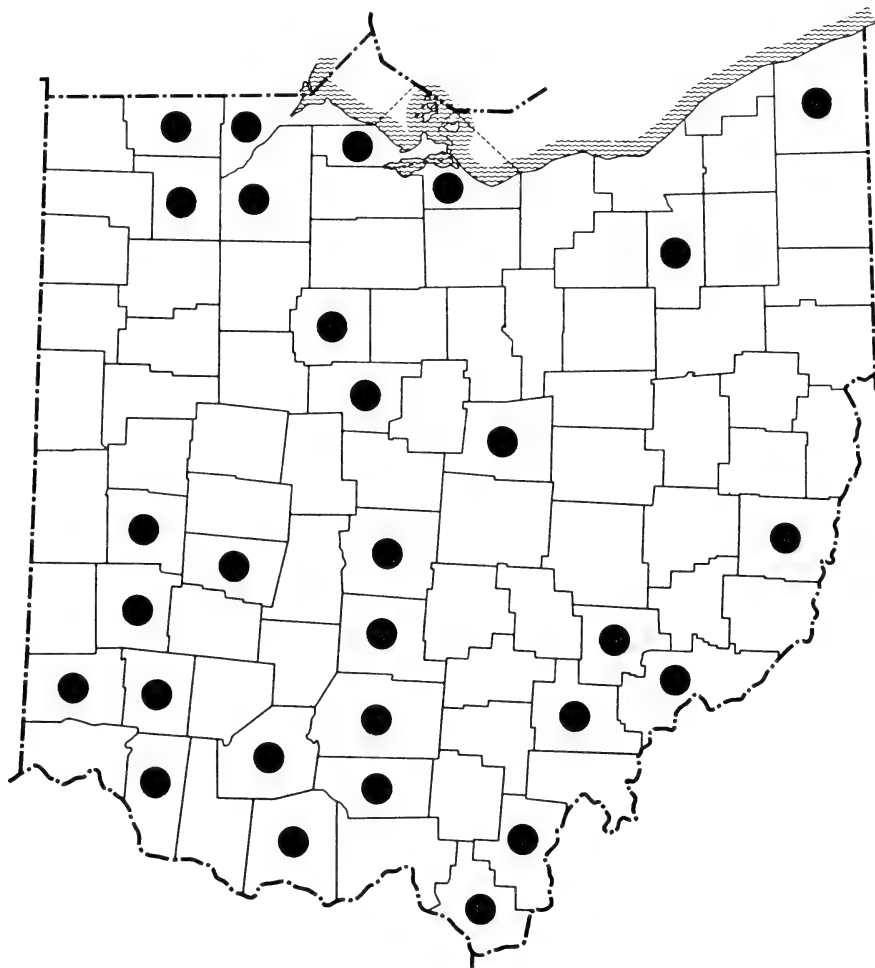


Fig. 2. The Ohio county distribution of *Lithospermum canescens*.

known as white puccoon. The sap in the thick taproots of both Ohio puccoons is abundantly supplied with a dark purple pigment which leaves a long-lasting stain upon the hands. Herbarium sheets on which 100 year old specimens of *Lithospermum* have been mounted still retain this purple color.

Lithospermum canescens (hoary puccoon) is widespread in Ohio in a variety of sunny, well-drained situations. Typical habitats include dry prairies, river bluffs, and rocky roadbanks. Hoary puccoon usually grows in calcareous substrates; occasionally, in sand. It is somewhat similar to plains puccoon with which it often occurs in northwest Ohio. The differences between these taxa are outlined following the discussion of the next taxon.

Lithospermum caroliniense (Walt.) MacM. subsp. ***croceum*** (Fernald) Cusick, comb. nov., based on *Lithospermum croceum* Fernald, Rhodora 37: 329. 1935. (Fig. 3)

Plains puccoon is one of the showiest wildflowers of the Great Lakes region. It occurs locally in open sandy habitats along Lake Erie and in the Oak Openings of northwest Ohio. It also has been reported from grassy fields on limestone hills. Plains puccoon may no longer be extant in northeast Ohio and it is nowhere common in the state. *Lithospermum caroliniense* subsp. *croceum* (as *L. croceum*) is protected as a threatened species in Ohio (ODNR, 1984).

Plains puccoon has been confused at times with the more frequent *L. canescens*. Where the two puccoons grow together in northwest Ohio their

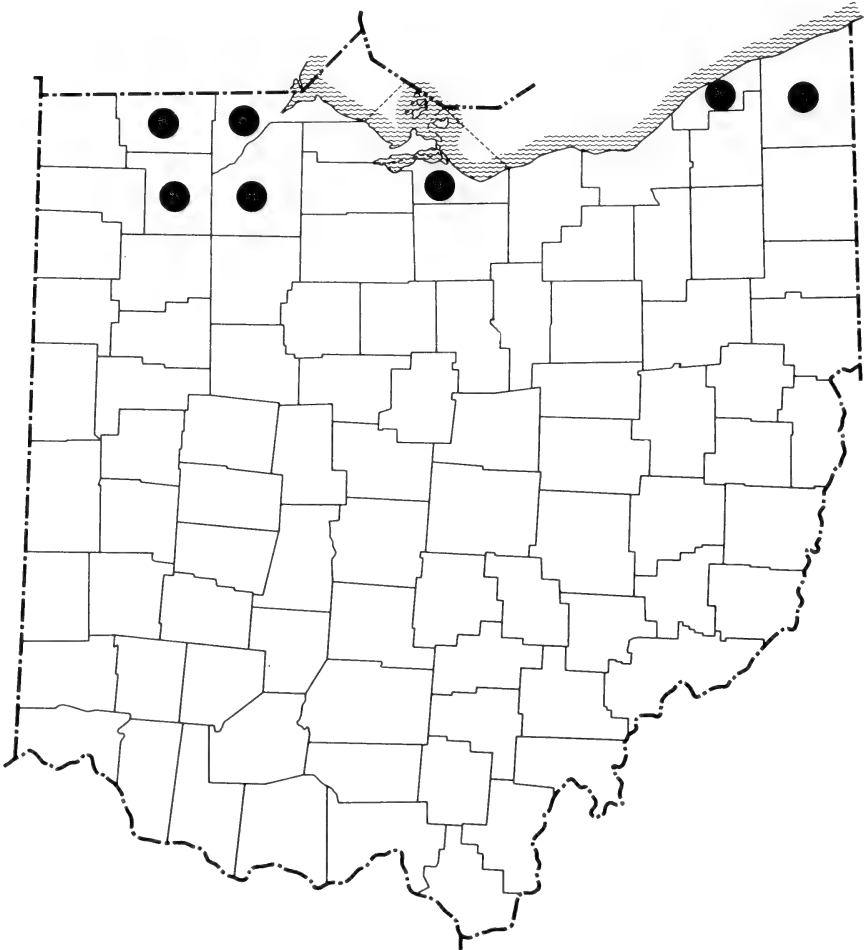


Fig. 3. The Ohio county distribution of *Lithospermum caroliniense* subsp. *croceum*.

peak blooming periods do not coincide. *Lithospermum canescens* flowers from early to late May; *L. caroliniense*, from late May to mid June. The number of flowering stalks arising from the crown of the deeply-buried taproot is a useful field character. *Lithospermum canescens* usually has five or fewer flowering stalks per plant, while *L. caroliniense* has many more, often a dozen. One exceptional plant of plains puccoon in Lucas County bore 44 flowering stalks.

Fernald (1935) described *Lithospermum croceum* from the Lake Michigan beaches near Manistique, Michigan. He also summarized the nomenclatural history of this previously unrecognized taxon. As defined by Fernald, *L. croceum* ranges from southern Ontario to Montana, south to western New York, Pennsylvania, Ohio, Indiana, Illinois, Missouri, and Kansas. *Lithospermum caroliniense*, in Fernald's interpretation (1935, 1950), occurs on the Atlantic coastal plain from southern Virginia to northern Florida, west along the Gulf Coast to eastern Texas and Mexico, and north in the Mississippi Embayment to Arkansas and southern Missouri. The two taxa are not at all sympatric. Johnston (1952) in his revision of *Lithospermum* dismissed *L. croceum* with but a single sentence, considering this taxon as part of his broad concept of *L. caroliniense*. Johnston's treatment is followed by many authors: Gleason & Cronquist 1963; Kartesz & Kartesz 1980; Jones & Fuller 1955; Roberts & Cooperrider 1982, Steyermark 1963, and Weishaupt 1971. Fernald's interpretation is followed by Mohlenbrock (1958) and Swink & Wilhelm (1979).

This writer has examined numerous specimens of both taxa from all parts of their total ranges without noting significant intergradation. *Lithospermum caroliniense* and *L. croceum* are certainly closely related, but a careful observer easily can separate them. The two taxa are similar, but distinctive, and their geographical distributions are almost exclusive. It seems logical to consider these taxa as subspecies.

The diagnostic characters of *Lithospermum canescens* and the two subspecies of *L. caroliniense* can be summarized as follows:

Lithospermum caroliniense subsp. *caroliniense*

pubescence stiff, the hairs with slender bases; mature calyx lobes flat, 1–1.5 cm; usually less than 25 foliage leaves below inflorescence.

Lithospermum caroliniense subsp. *croceum*

pubescence stiff, the hairs with pustular bases; mature calyx-lobes strongly keeled, 1–1.5 cm; usually more than 30 foliage leaves below inflorescence.

Lithospermum canescens

pubescence soft, the hairs with slender bases; mature calyx-lobes flat, 6–8 mm; usually less than 25 foliage leaves below inflorescence.

EXCLUDED SPECIES

The following literature reports of *Lithospermum* taxa all may be assigned to *L. caroliniense* subsp. *croceum*: *L. hirtum* Lehm. (Kellerman &

Werner 1893; Moseley 1899); and *L. gmelini* (Michx.) Hitchc. (Moseley 1928; Schaffner 1932; Transeau & Williams 1929). These names often were applied to specimens of *L. caroliniense* subsp. *croceum* collected prior to Fernald's description of *L. croceum* (1935).

Lithospermum incisum Lehm. (as *L. angustifolium* Michx.) was reported from northern Ohio by Kellerman & Werner (1893). This puccoon grows from southern Ontario to western Canada, south to Indiana, Missouri, and northern Mexico. It is decidedly rare in the Great Lakes region (Argus & White 1977; Swink & Wilhelm 1979). While the occurrence of *L. incisum* in Ohio would not be improbable, I could not find any specimens substantiating this report. Specimens labelled as such proved to be *L. caroliniense* subsp. *croceum*.

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NOTICE

Although we have some complete sets of back issues still available, our stock of the following issues is very low: Vol. 1 No. 1 & 2, Vol. 2 No. 1, Vol. 4 No. 3, Vol. 5 No. 1 & 3A, Vol. 7 No. 4 and Vol. 19 No. 3. If you have these issues and believe that they would be of better use to others we would greatly appreciate their return. We would be pleased to reimburse you for postage if requested. Please send these issues to the following address:

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Carex
CAREX HIRTA, NEW TO WISCONSIN

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On June 25, 1982, we collected a specimen (*Freckmann and Bogdansky* 18142 UWSP) from a single large clone of a sedge growing in disturbed sandy soil along the Soo Line Railroad track at the southeast edge of the City of Marshfield, Wood Co., near the geographic center of Wisconsin. We have subsequently confirmed our identification of this sedge as *Carex hirta* L., a native of Europe and the type species of the genus. It is reported to be naturalized locally in the northeastern United States and adjacent Canada west to Michigan (Fernald, 1950; Gleason & Cronquist, 1963; Voss, 1972; and Scoggan, 1978). It can be recognized in the field by a combination of features: a coarse rhizome producing small clumps of culms at intervals of about 10 cm; densely hirsute sheaths; and hairy, strongly-ribbed perigynia about 5–8 mm long. This appears to be the first Wisconsin record of this species.

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*Nature education feature --*245 **USING LICHENS TO MONITOR ACID RAIN
IN MICHIGAN**

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Lichens are inconspicuous little plants that blend in with their substrates even though they are often brightly colored and have interesting growth patterns. Once you begin to notice them, they seem to be everywhere where the air is clean. In addition to their occurrence on human-made substrates, lichens may be found on tree bark, barkless wood, rock, or soil.

Lichens consist of two unrelated components, fungi and algae, living in close association. Experts have disagreed on the nature of this association ever since 1867 when Schwendener made the startling announcement that lichens were a dual entity rather than a single organism. Schwendener proposed a parasite-host relationship with the fungal hyphae taking nourishment from the enslaved algae. Other researchers have suggested a symbiotic association with both partners benefiting. Whatever the exact nature of the association, lichens have been successful in invading the harshest of habitats from arid deserts to arctic rocks. According to Rudolph (1967), 350 species of lichens are found in Antarctica, compared with two species of vascular plants. This successful group of diverse plants has an estimated number of species of about 20,000.

The scientific names of lichens refer only to the fungal partners (mycobionts) that are Ascomycetes except for a very few Basidiomycetes and some Fungi Imperfecti. Over half of all known Ascomycetes are lichenized. Isolated mycobionts are found only rarely in nature, and it is well known that they need an appropriate alga to survive under natural conditions. The algal partners (phycobionts) are most commonly green algae with a few blue-green algae. The three genera, *Trebouxia*, *Trentepohlia*, and *Nostoc* are found in 90% of all lichens.

Lichens are traditionally grouped according to one of three growth forms: the crustose form, the leaf-like foliose form (Fig. 1), and the shrubby or hairlike fruticose form (front cover). Scientific classification is based on the fungal spores or the asexual fragmentation of the lichen thallus. Only the mycobiont is involved in sexual reproduction, and upon germination, the fungal hyphae must find a suitable alga in order to form a thallus. In asexual reproduction, combined algal and fungal partners are dispersed, generally as isidia or soredia. In contrast to the rapidly growing free-living fungal species, (e.g. mushrooms), lichens grow very slowly and have considerable longevity. According to Hawksworth and Rose (1976), growth in crustose and foliose species is mainly marginal, producing rosette-like plants that add

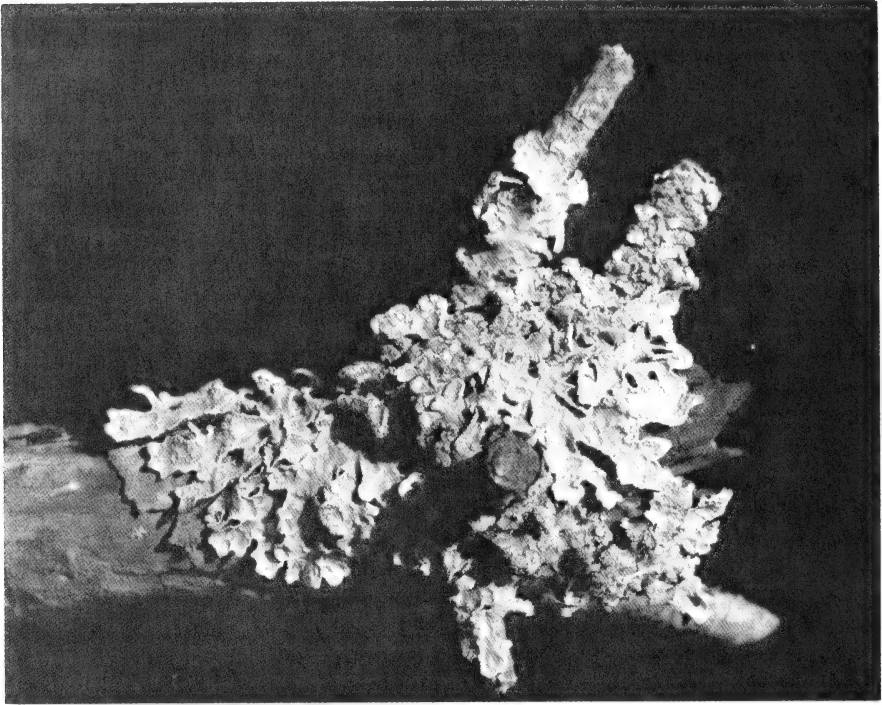


Fig. 1. *Parmelia sulcata*, a foliose lichen that grows on bark.

from one-half to five mm to their radius per year. Fruticose species may grow apically at a rate of one to two cm per year. Estimations of lichen age are as high as 4500 years for specimens in Greenland. Lichens absorb some minerals from their substrate, but most of the elements taken up by lichens are derived from the air and rainwater. When the phycobiont is a blue-green alga, nitrogen fixation may occur.

Under conditions of dryness or low temperature, lichens become metabolically and chemically inert. The upper layer of the lichen thallus is opaque when dry and transparent when wet, allowing photosynthesis to occur under favorable conditions and protecting the phycobiont from sunlight during unfavorable conditions.

Although lichens can survive adverse natural conditions, they are especially vulnerable to acid rain and air pollution. The inability of lichens to excrete toxic elements, coupled with their efficient mechanisms for accumulation, enhances their susceptibility to atmospheric pollution. Because lichens are so sensitive to pollution, they are the first plants to disappear in cities. As the center of a city or industrial center is approached, certain basic trends in lichen vegetation may be observed. Fruticose lichens disappear first, followed by foliose lichens, and then crustose lichens, and finally even powdery lichens are lost from the environment (Brodo, 1966).

After the legislation in 1970 and 1977 for clean air, the air in cities appeared to be cleaner because of removal of particulate matter and installation of taller smokestacks that transported the problem farther away. However, lichens continue to be lost from urban environments. The reason for this seems to be related to the sulfur and nitrogen oxides produced by the burning of fossil fuels. In the atmosphere, these substances are oxidized to sulfate and nitrate aerosols. If moisture (rain, snow, dew, mist) is present, sulfuric and nitric acids are formed. The air-borne droplets can be deposited in dry weather or fall with precipitation. Gilbert (1970a) analyzed lichens for their sulfur content and found levels thousands of times greater than air concentrations present in proportion to the amount of sulfur dioxide in the air where the lichens were growing. Skye (1968) was able to show a high correlation between sulfur dioxide pollutants and the quantity of lichen vegetation. Color changes seen in the affected lichens were attributed to chlorophyll destruction.

The deleterious effect of sulfur dioxide has been demonstrated in laboratory experiments. Rao and LeBlanc (1966) subjected several corticolous lichens to controlled amounts of sulfur dioxide at various humidities and found that the algal components were extremely sensitive to injury by sulfite and sulfate ions. The symptoms of injury were bleaching of chlorophyll, permanent plasmolysis, and the formation of brown spots on the chloroplasts. They concluded from the analysis of pigments extracted from the treated lichens that chlorophyll-a had been degraded to phaeophytin-a. Since lichens have relatively little chlorophyll per plant mass compared with other plants, the presence of sulfur dioxide could upset the delicate balance between fungal and algal partners.

As the price of oil and natural gas rises, as surely it will, the use of coal by industries and power generation plants will increase. Increased use of coal has the potential to greatly add to the acid rain problem. It is therefore important to establish baseline estimates of sulfur and nitrogen oxide levels and also be able to detect an increase in concentration of these noxious gases in the future. And ideal monitor of environmental hazards must be reliable, inexpensive, take into account the complex factors of air pollution as they affect life itself, and operate 24 hours a day, all year long.

The best monitors to detect adverse conditions for life processes are living organisms, for example, the miner's canary. Plants, because they are stationary, are exposed continuously to the substance being monitored. Lichens are long-lived, widely distributed, and, unlike other plants, go in and out of dormancy throughout the year, and thus are metabolically active during all seasons when moisture conditions are suitable.

The value of lichens as biological indicators of air pollution has been recognized in the past. Zone maps of lichen species distribution were prepared for many European and North American cities in order to study patterns of air pollution. Since lichens vary in their sensitivity to sulfur and nitrogen oxides (acid rain), an estimation of air pollution can be made on the basis of the species present in an area. Hawksworth and Rose (1976) developed a system with ten zones of air pollution that employed several

species of lichens per zone. Skye (1968) and Gilbert (1970b) were able to attach tentative sulfur dioxide levels to some of the lichen zones. An index of atmospheric purity (IAP) proposed by LeBlanc and DeSloover (1970) uses species diversity and abundance of growth to give a quantitative estimation of air quality. Brodo (1961) transplanted lichens, along with a core of bark on which the lichens were growing, to similar trees growing in New York City and noted the survival time of the lichens. He found that the greater the degree of air pollution, the shorter the survival time.

Michigan has a rich variety of lichen species. Harris (1977) estimated the total number of species in Michigan to be as high as 700. Over 40% of the macrolichens described in Hale's key (1979) to lichens in the United States are found in Michigan, although by far the greatest variety of species are found in the northern areas of the state.

The author would like to propose that Michigan botanists take more interest in lichens and begin making an inventory of the species in their areas. Some lichens are rather more difficult to identify than other plants because simple chemical tests and microscopic examination of spores may be required to differentiate them. However, many species are easily recognized at sight. Of course, structures that are unique to lichens must be recognized to follow classification keys. Lichens are easy to collect and may be preserved simply by drying. The identity of a specimen can be confirmed at a later time.

A standing committee of the Michigan Botanical Club could be established to aid Michigan botanists in making an inventory of the lichen floras of their areas by: setting up a special herbarium of vouchers, using referees for determination of species, and compiling a total list of species by area from lists contributed by individuals. Eventually this data could be used for mapping of the areas studied. Knowledge of the numbers and kinds of lichens present could give an estimate of the relative air quality today (as related to acid rain conditions) and serve as a valuable baseline for future comparisons.

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NOTICE

One of the jobs of the editor is to nominate members of the editorial committee. The Board of Directors of the Michigan Botanical Club reviews the nominations and makes the appointments. We are happy to report that the people listed below have agreed to serve on the editorial board and have been appointed.

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James Pringle, Royal Botanical Gardens, Hamilton, Ontario

Richard K. Rabeler, Michigan State University

Donna Schumann, Western Michigan University

Edward G. Voss, University of Michigan

We look forward to working with the new editorial board in our efforts to maintain the high quality of *The Michigan Botanist*.

JIM and NANCY WEBER

REVIEW

THE FLORA OF MANITOULIN ISLAND, second revised edition. By J. K. Morton and Joan M. Venn, illustrated by Donald R. Gunn. University of Waterloo Biology Series No. 28. 181 pp + 106 map plates. Available from Dept. of Biology, University of Waterloo, Waterloo, Ontario, N2L 3G1. Canada. \$20.00 CAN.

Here is a fine local flora concerning a most interesting area. The limestone and dolomite pavement ("alvar") that covers so much of Manitoulin and associated islands has some of the most distinctive and interesting vegetation and flora in the Great Lakes region.

Although large areas of alvar occur in eastern and southern Ontario, and smaller areas locally in northern Michigan, northwestern Ohio, and northeastern Wisconsin, Manitoulin Island has probably the largest contiguous area of alvar. Manitoulin certainly has a very rich flora associated with its alvars, including such distinctive alvar species as *Hymenoxys acaulis* var. *glabra* (a Great Lakes endemic), *Geum triflorum*, *Isanthus brachiatus*, and *Myosotis verna*.

Introductory material for this flora covers in some detail, geology, glacial history, climate, botanical exploration, vegetation and plant distribution. The flora contains 1167 species, with species and genera arranged alphabetically and families in the order of Gray's Manual of Botany, 8th Ed. For each species, relevant synonymy, common names, habitat, flowering or fruiting dates, and abundance are noted. Additional discussion and references are given where appropriate. The comments are based on original field experience. For taxonomically difficult species, the notes are often extensive and very helpful, e.g., *Echinochloa crus-galli*, *Poa* sp., *Nymphaea odorata*, *Thalictrum dasycarpum*, *Oxalis fontana*, and *Arctium minus*.

Helpful, original keys to difficult groups are interpolated throughout the text, appearing unexpectedly after one (not necessarily the first) of the species of the group—with the rest of the group scattered elsewhere by the vagaries of the alphabet. Fortunately, keys and species are cross-referenced.

Nomenclature has been thoroughly updated to incorporate recent research. However, new names have generally not been merely uncritically taken-up, but have been discussed. This flora is useful for this contribution. Few nomenclatural corrections have been overlooked, although Schuyler's discovery (Rhodora 76: 51. 1974) that *Scirpus pungens* is the correct name for *S. americanus* is not mentioned, and the name *Betula lutea* is used even though clearly illegitimate. The use of the name *Malus sylvestris* for the common pear is puzzling. Generic delimitation generally follows "traditional" North American usage. This may be somewhat inconsistent, but does reduce the number of name changes for reasons purely of taxonomic opinion as opposed to nomenclatural rules—as may be appropriate to a local flora.

Two additional, very nice, features are part of this book. Superb, well-reproduced color photographs mostly by Donald R. Gunn illustrate 124 species. These are a special treat and make the book more useful to beginners. Distribution maps are also given for every species known from two or more localities.

In short, this is an accurate, information-filled, useful flora, based on extensive field work, of one of the most interesting areas in the Great Lakes region. It will be helpful to everyone interested in the flora of the Great Lakes region, whether amateur or professional.

—A. A. Reznicek

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**BUXBAUMIA APHYLLA HEDW. NEW TO MINNESOTA
AND NOTES ON SOME OTHER MOSSES LITTLE KNOWN
IN THE STATE**

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Some mosses recently collected along Big Trout Creek in southeastern Minnesota are either new to the state or have not been collected in Minnesota for over 75 years and are represented in the University Herbarium by only a few specimens. Motivated by these finds, similar habitats in other localities in the southeast are now being searched for these and other mosses rarely found in the state. All specimens cited are in the University of Minnesota Herbarium (MIN).

Buxbaumia aphylla Hedw., the Elf Cap Moss, is reportedly rare and local but widely distributed in the Northern Hemisphere (Crum and Anderson, 1981). It has been reported from northeastern Iowa (Crum and Anderson, 1981) and northern Wisconsin (recorded for Vilas County by Bowers and Freckmann, 1979) but not from Minnesota. A single fruiting plant was observed along a narrow, woodland trail near the top of a north-facing, forested slope overlooking Big Trout Creek, which is approximately 13 km southeast of Winona in Winona County. The moss was growing in partial shade. Other mosses in proximity were *Atrichum undulatum*, *Plagiomnium cuspidatum*, *Tetraphis pellucida* and *Thuidium delicatulum*. Although this species is very inconspicuous, particularly when the capsules are mature and dark colored, it is easily recognized by the large, tear-shaped capsule that is quite oversized in proportion to the other, almost nonexistent, parts of the plant (Crum, 1976). An intensive search of the vicinity failed to yield additional fruiting specimens or other evidence of the species, such as scattered masses of brownish-green protonema.

Aulacomnium heterostichum (Hedw.) BSG is represented in the University Herbarium by only a single specimen (Winona Co., near Queen's Bluff, collected by J. M. Holzinger, May 25, 1901), and has not been collected in the state for over 80 years. This moss was observed by the author at the same site as *Buxbaumia aphylla*, but near the bases of trees in deep shade. Other mosses in proximity were *Anomodon attenuatus*, *Bartramia pomiformis*, *Entodon cladorrhizans*, and *Plagiomnium cuspidatum*. *Aulacomnium heterostichum* is reported as widespread in eastern North America, particularly in oak-hickory forest farther southward (Crum and Anderson, 1981). In Wisconsin (Bowers and Freckmann, 1979) it is reported from three southwestern counties. Unlike other species in the genus, this moss mostly lacks brood bodies and has relatively broad, second leaves that are coarsely toothed above the middle (Crum and Anderson, 1981).

Another moss that has not been collected in the state for over 75 years is *Fissidens obtusifolius* Wils. Prior to the Big Trout Creek collection, it was known by two specimens from Winona County and one from Blue Earth County. Along Big Trout Creek numerous plants of this species were observed on the wet roof of a cave partially silted-in by creek waters, although near the cave mouth it is largely replaced by species such as *Funaria hygrometrica*, *Leptobryum pyriforme*, and *Physcomitrium pyriforme*. According to Crum and Anderson (1981), this endemic North American species has an essentially eastern distribution, but it is also known from a limited number of stations west of the Mississippi River. In Wisconsin (Bowers and Freckmann, 1979) it is reported from two southwestern counties. This small, distinctly flattened plant, which apparently is a calciphile, is best distinguished by leaves that have broad or rounded tips and entire margins (Crum and Anderson, 1981).

All of the mosses mentioned above were collected from near what is sometimes called the La Moille Cave site. Of some interest, the rare *Bryoxiphium norvegicum* (Brid.) Mitt., the Sword Moss, was collected in and around La Moille Cave (1883–1905) by the noted bryologist John M. Holzinger. More recently, Peck (1980) reported the plant as extirpated from this site and suggested that highway construction in the area and water impoundment on the Mississippi River caused the cave to be partially filled in with silt. Unfortunately, recent efforts by the author and others to recollect the species from caves near La Moille have also been unsuccessful. Although there are no known extant sites for *Bryoxiphium norvegicum* in Minnesota, the species is reported from seven sites in southwestern Wisconsin (Bowers and Freckmann, 1979) and two sites in northeastern Iowa (Peck, 1980). It is hoped that future collecting in the southeast will restore this celebrated rarity to the ever-increasing list of bryophytes known to occur in the state.

REPRESENTATIVE COLLECTIONS

Buxbaumia aphylla Hedw. Winona Co.: approximately 13 km SE of Winona on Rte. 61, on soil near top of a wooded bluff overlooking Big Trout Creek, T106N, R5W, Sec. 7, *Wheeler B-818*.

Aulacomnium heterostichum (Hedw.) BSG. Winona Co.: approximately 13 km SE of Winona on Rte. 61, base of tree, wooded bluff overlooking Big Trout Creek, T106N, R5W, Sec. 7, *Wheeler B-827*.

Fissidens obtusifolius Wils. Winona Co.: approximately 13 km SE of Winona on Rte. 61, wet roof of cave along Big Trout Creek, T106N, R5W, Sec. 7, *Wheeler B-842*.

ACKNOWLEDGMENTS

I wish to thank Dr. Jan A. Janssens for valuable advice on the manuscript; and Profs. Gerald B. Ownbey and Clifford M. Wetmore for use of the University of Minnesota Herbarium facilities.

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NOTICE

The fourth Midwestern Bryological Foray will be held September 20-22, 1985 at the Cusino Lake Field Station of Northern Michigan University. Professionals, students, and amateurs are cordially invited to participate. If interested, further information is available from Dr. Maynard Bowers, Department of Biology, Northern Michigan University, Marquette, Michigan 49855. (906) 227-2443 or 227-2310.

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*On the cover: Cladonia phyllophora,
a fruticose lichen that grows on soil; photo by Julie Medlin.*

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THE

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Articles dealing with any phase of botany relating to the Upper Great Lakes Region may be sent to the co-editors. In preparing manuscripts, authors are requested to follow our style and the suggestions in "Information for Authors" (Vol. 15, p. 238).

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Membership in the Michigan Botanical Club is open to anyone interested in its aims; conservation of all native plants; education of the public to appreciate and preserve plant life; sponsorship of research and publication on the plant life of the State; sponsorship of legislation to promote the preservation of Michigan native flora and to establish suitable sanctuaries and natural areas; and cooperation in programs concerned with the wise use and conservation of all natural resources and scenic features.

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**HELLEBORINE—A 30-YEAR UPDATE AND ANALYSIS
OF ITS DISTRIBUTION IN ONTARIO**

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BACKGROUND

Some thirty years ago an account was given and a distribution map presented (Soper & Garay 1954) summarizing the spread in Ontario of the introduced orchid known as Helleborine [*Epipactis helleborine* (L.) Crantz]. The starting point was its first reported occurrence in the province, namely on the Humber River near Lambton Mills in York County (West Toronto Junction, now within the limits of metropolitan Toronto), based on a collection by Messrs. W. & O. White, July 1890 (specimen in CAN, No. 16431). In the sixty-four years following its discovery, this orchid had been found in thirty-four other counties or districts as far away from Toronto as Ottawa, over 200 miles (*ca* 340 km) to the northeast, northward on the Bruce Peninsula, westward to the southeastern shore of Lake Huron and southward to the tip of Long Point, Lake Erie.

When the earlier map was published, no reports had been seen from any part of northern Ontario, nor from the districts of Haliburton, Muskoka, Parry Sound, Nipissing or Renfrew in the central part of the province. Similarly, no records were known for the occurrence of Helleborine in the southwestern counties of Essex, Kent, or Middlesex at the western end of Lake Erie, nor had it been reported from the eastern counties of Dundas, Stormont, and Glengarry along the north shore of the St. Lawrence River. (For location of these counties and districts, see map, Figure 1.) The suggestion was made that this orchid would soon be picked up by local naturalists in those southern counties and that its apparent absence might be due to lack of collecting and field observations.

Since 1954 a large number of new records have accumulated and several botanists have kindly provided additional data from their records of personal observations in the field. We now have reports for all of the counties and districts mentioned above, with the exception of Nipissing, but it is likely that Helleborine occurs in that district since there are sites nearby in the northeastern corner of Muskoka and of Haliburton. With the large amount of new data now on hand, it seems appropriate to present an updated map and some other information which may be relevant to recent extensions of the range of *Epipactis helleborine* in Ontario.

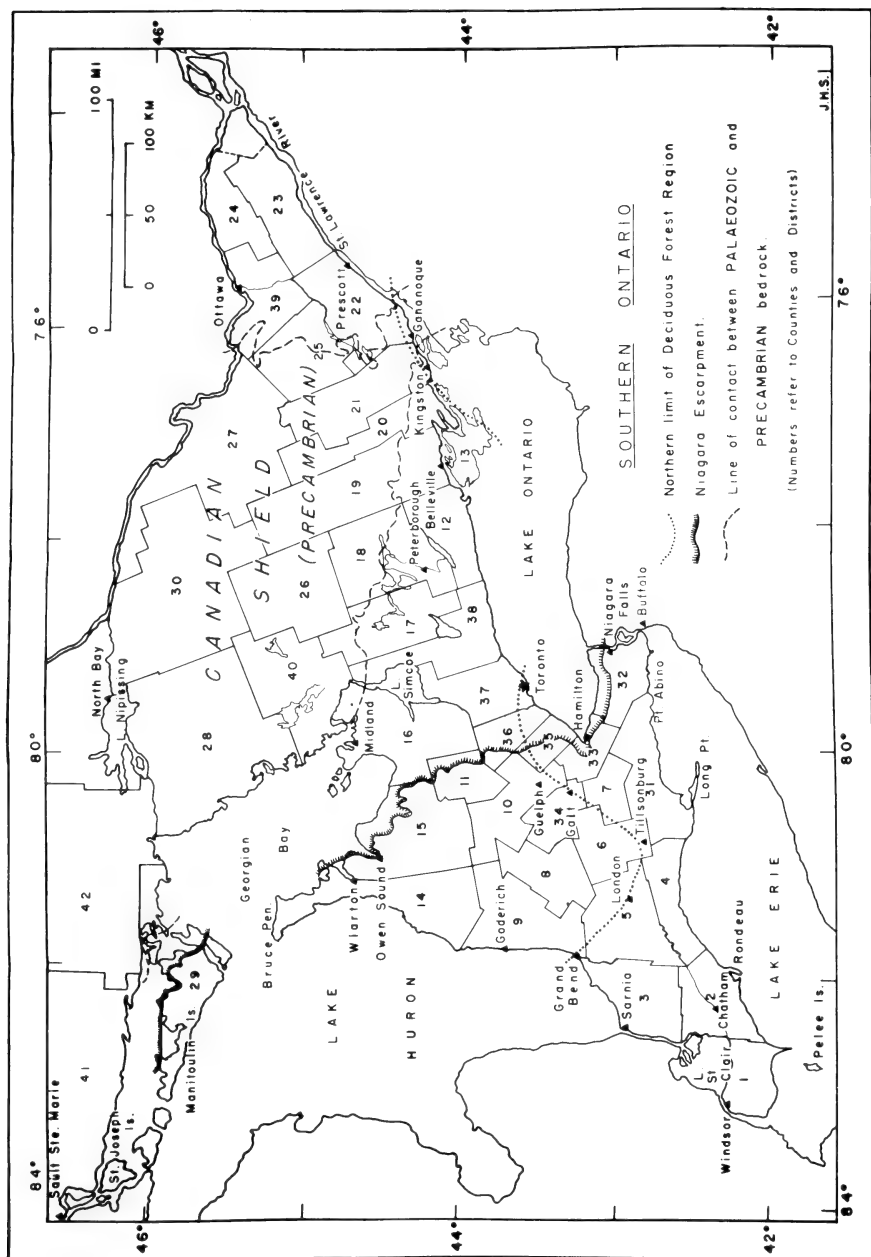


Fig. 1. Map of southern Ontario showing places mentioned in the text. Numbers indicate counties, districts and regional municipalities: 1. Essex, 2. Kent, 3. Lambton, 4. Elgin, 5. Middlesex, 6. Oxford, 7. Brant, 8. Perth, 9. Huron, 10. Wellington, 11. Dufferin, 12. Northumberland, 13. Prince Edward, 14. Bruce, 15. Grey, 16. Simcoe, 17. Victoria, 18. Peterborough, 19. Hastings, 20. Lennox & Addington, 21. Frontenac, 22. Leeds & Grenville, 23. Stormont, Dundas & Glengarry, 24. Prescott & Russell, 25. Lanark, 26. Haliburton, 27. Renfrew, 28. Parry Sound, 29. Manitoulin, 30. Nipissing, 31. Haldimand-Norfolk, 32. Niagara [Formerly Welland & Lincoln], 33. Hamilton-Wentworth, 34. Waterloo, 35. Halton, 36. Peel, 37. York, 38. Durham, 39. Ottawa-Carleton, 40. Muskoka.

ACCOUNT OF FURTHER INVESTIGATIONS

In 1964, the senior author, while still at the Department of Botany, University of Toronto, developed a method of plotting distribution maps on preprinted base maps using a mechanical tabulator. The data available for *Epipactis helleborine* were sorted by computer and a series of maps prepared by dividing the records by the date of collection or field observation. The data were then plotted on an I.B.M. 407 Accounting Machine. The first test map, prepared in March 1964, was published as an illustration in an article on the use of data-processing in mapping (Soper 1964, Fig. 7, p. 1096). This was followed in August 1964 by a series of maps (unpublished) showing the ranges at time intervals increased successively by ten years from the first recorded Ontario collection (1890). Although the 10-year interval was an arbitrary choice for dividing the records, several interesting trends were displayed by the eight maps in that series.

The maps showed no significant increase in the area occupied by *Helleborine* until the 1920s. By that time records were more numerous in the Toronto region and *Helleborine* had been found in two widely separated areas, namely, Peterborough (1921, F. Morris, CAN 16430) and Niagara Falls (1924, J. G. Wright, TRT 15798).

In 1930 Hoyes Lloyd found *Helleborine* on his home property in Rockcliffe Park, Ottawa, and in the same year a Toronto naturalist, Hubert Brown, collected it at Mountain Lake, Prince Edward County (on the north shore of Lake Ontario). By 1939 other sites had been discovered at Hamilton, at Point Abino on Lake Erie, and at Tillsonburg in Oxford County.

By 1949 some gaps were beginning to be filled in and two new disjunct populations had been recorded, one in Huron County and the other in Grey County.

Between 1949 and 1959 there was a rapid increase in new sites for *Helleborine* with many northward extensions into the Precambrian Shield country and numerous sites close to the shores of Georgian Bay and Lake Huron (south of 45° N), the eastern half of the north shore of Lake Erie and along the north shore of Lake Ontario and the St. Lawrence River. Although collections had been made in Rondeau Park by that time, there were no other records for the main part of Kent County, or adjacent portions of Lambton, Middlesex, and Elgin Counties, nor for any part of Essex County.

In 1967, in the course of providing data for testing the feasibility of a computer-assisted plotting routine, the records of *Epipactis helleborine* that had accumulated were plotted on a CalComp Plotter (see Soper 1969, 1975) using a base map of southern Ontario that had been digitized for machine-plotting (Figure 2). A comparison of this map with one showing collection localities in southern Ontario between 1940 and 1967 (Figure 3) suggests that *Helleborine* probably was indeed absent in some areas that appeared as blanks on the 1967 map. The best example is Manitoulin island, where numerous collections and field observations up to 1967 failed to uncover a single occurrence of *Helleborine*.

Since 1967 there has been a continual filling in of gaps and an extension of the range up to the tip of the Bruce Peninsula and across onto Manitoulin

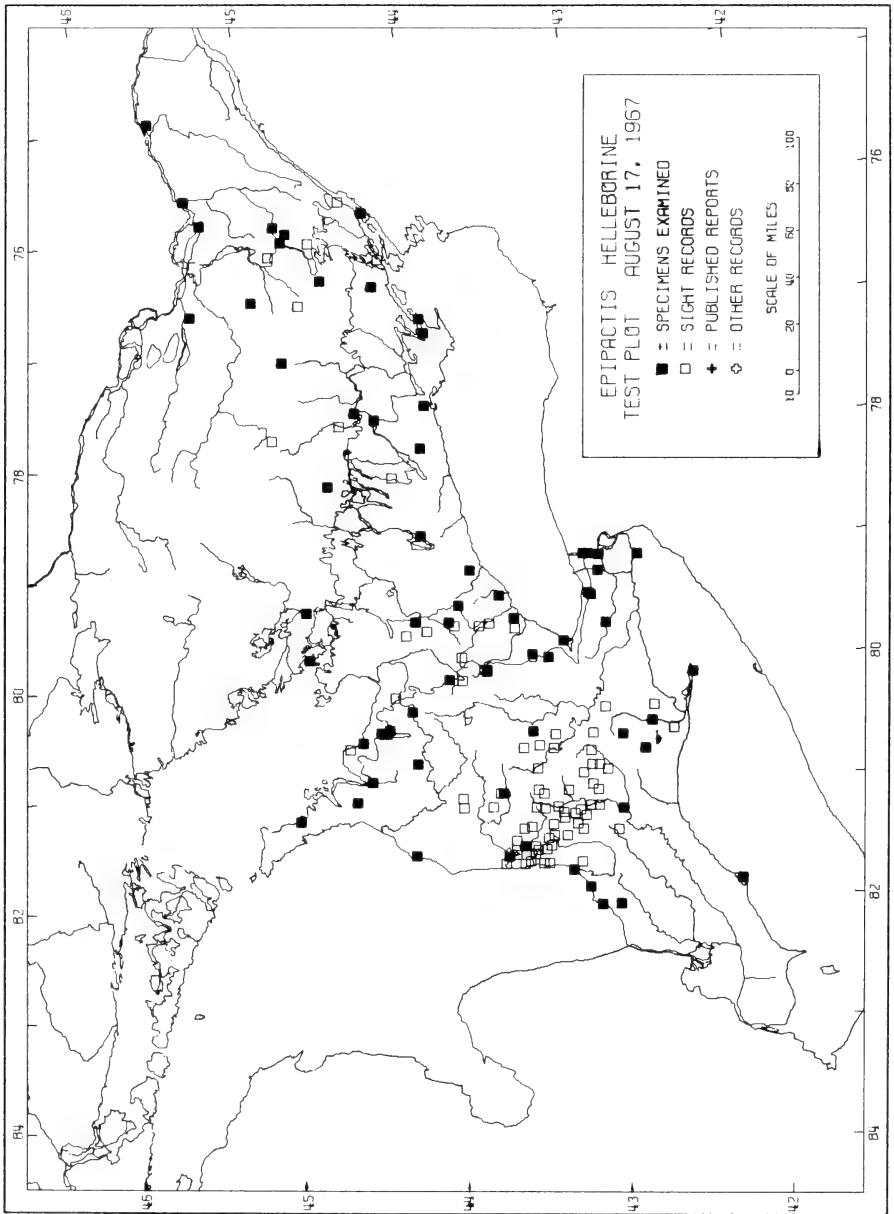


Fig. 2. Distribution records for *Epipactis helleborine* in southern Ontario from 1890 to 1967.

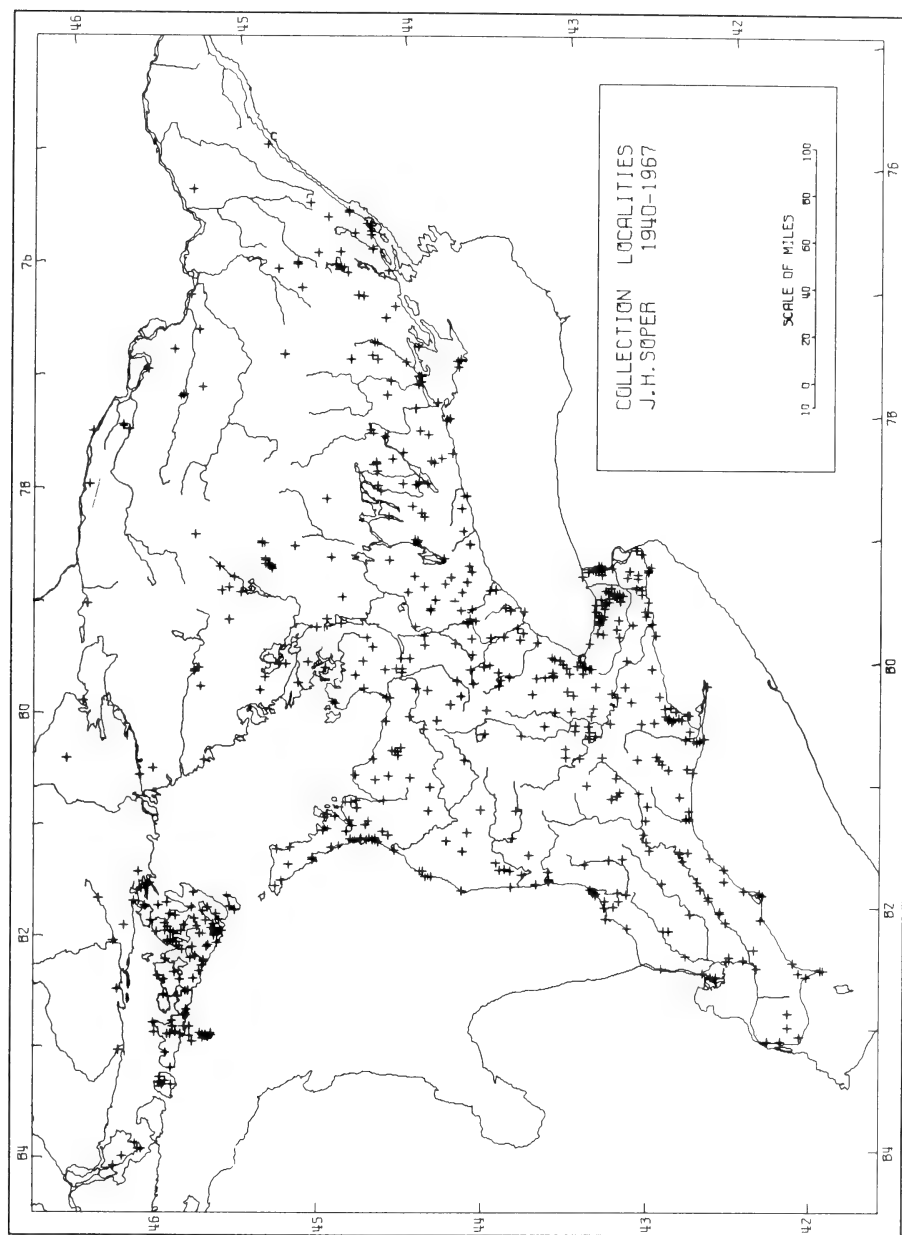


Fig. 3. Locations in southern Ontario at which plant collections and sight lists were made between 1940 and 1967.

Island. In 1973 E. W. Greenwood found five localities for Helleborine in the eastern half of Manitoulin Island, thereby substantiating the prediction (see Greenwood 1974) that this species would undoubtedly spread onto that island.

For the vicinity of Ottawa there are detailed records for the distribution of Helleborine due to the efforts of a group of local naturalists. In 1966 E. W. Greenwood initiated the Native Orchid Location Survey (Greenwood 1967), which was an ambitious project to record and computerize the locations and abundance of all native orchids in Canada. The Orchid Location Survey reported that Helleborine had been found in more locations (142 out of 913) than any other orchid (Greenwood 1967). Ten years later, Helleborine was still the most common orchid in the Ottawa Study Area, with 377 records (Reddoch 1977).

An account of this project and its subsequent restriction in 1975 to activity in the Ottawa Study Area was given by Joyce Reddoch (1977) and included a distribution map of Helleborine. The map shows numerous records throughout the Ottawa Study Area, which now extends from 45° 00' to 46° 00' N and from 75° 00' to 76° 30' W. This is an enlargement from the traditional "Ottawa District", the area encompassed by a circle of 30-mile radius around the centre of Ottawa. Both areas include lands on the Ontario and Quebec sides of the Ottawa River.

A significant extension of range has been provided by a recent collection of *Epipactis helleborine* from St. Joseph Island, Algoma District, southeast of Sault Ste. Marie (1981, D. F. Brunton, CAN 458722). A more spectacular extension is the report from the Timiskaming District (Bryan and Newton-White 1978) which is undoubtedly authentic, although we have not seen a specimen from that area. The latter would be the northernmost record for Ontario and for North America.

We now have records for over 600 sites in Ontario and these have been plotted on the map (Figure 4). Excluding duplicate collections seen in different herbaria, the data include over 350 specimens examined, 250 sight records and a small number of reports taken from the literature. In the case of the Ottawa Study Area the scale of our map (Figure 4) has made it impossible to use all the records currently available, so we have plotted only a small sample to fill out the range in that region.

ANALYSIS OF DISTRIBUTION DATA

On examining our updated map, it is seen that Helleborine has not yet been reported from all parts of southern Ontario. The most obvious blank spot is still the area in the counties of Essex, Kent, Lambton, and adjacent portions of Middlesex. Helleborine was not listed for Point Pelee by Dodge (1914) nor for the Erie Islands (including Pelee Island) thirty-four years later by Core (1948). In spite of the appearance of Helleborine in Rondeau Park by at least 1957, we had no further reports from this large area until the July

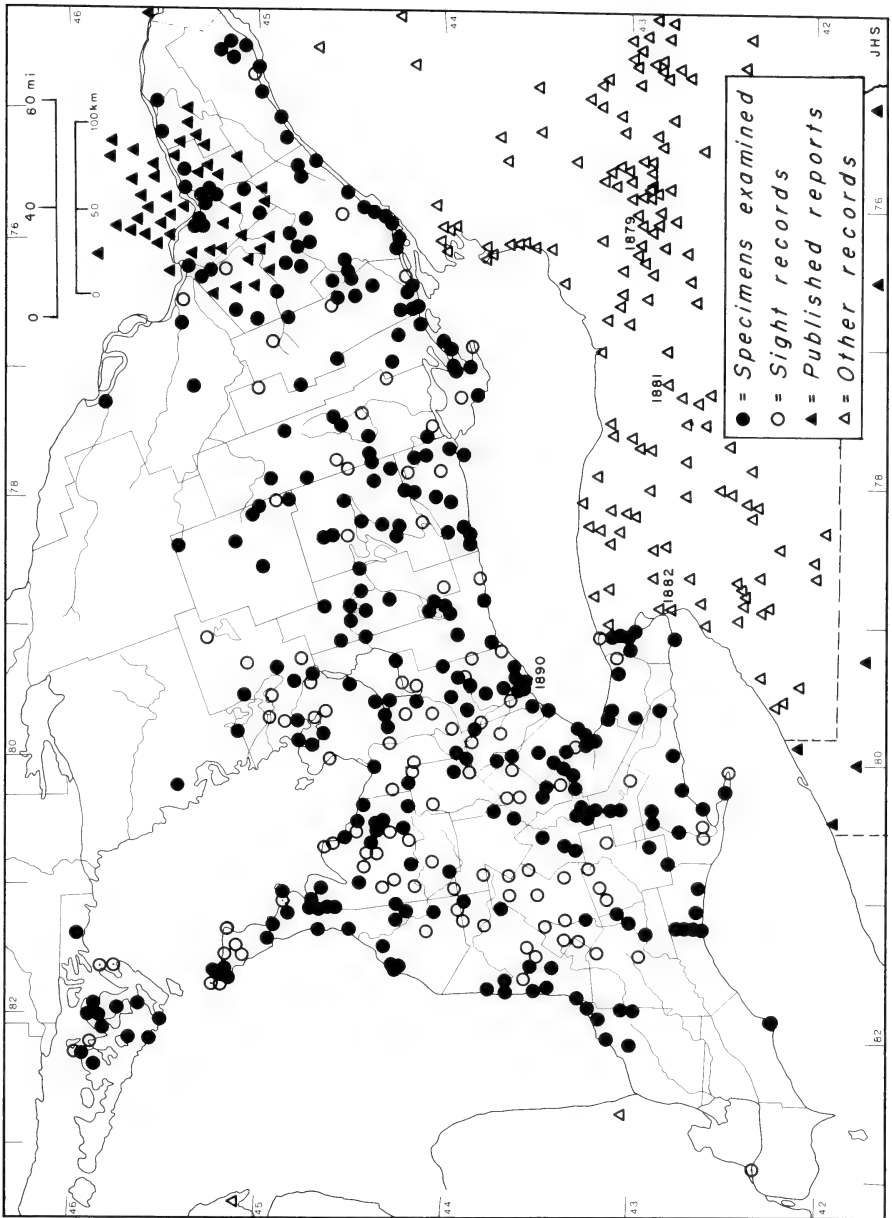


Fig. 4. Distribution of records for *Epipactis helleborine* in southern Ontario and adjacent areas from 1890 to 1984.

1981 sighting on Peche (Peach) Island (in Lake St. Clair, just NE of Sarnia) by (Mike) Oldham (see Botham 1981, p. 195).

The other blank area is in that part of eastern Ontario which lies between the St. Lawrence and Ottawa Rivers. This region is known to have been neglected by botanists for many years but has recently begun to receive more attention. Unless the habitats in that area are unsuitable for Helleborine, it is reasonable to assume that the area will eventually be invaded by this orchid.

As the publication of all our intermediate stage maps does not seem warranted, we have attempted to illustrate some of the "waves" of migration and establishment of Helleborine in Ontario on a single map (Figure 5). The shaded areas have been plotted using our series of 10-year interval maps, with the exception of the first (darkest) category which covers the period from first discovery (1890) up to 1929. The next four shadings show the areas in which records date in the 1930s, 1940s, 1950s, and 1960s, respectively. The final period has been extended to cover the years from 1970 to date, since we have few records as yet for the 1980s.

Unfortunately, both the Timiskaming and the St. Joseph Island records fall outside the plotting area of our base map, but the location of St. Joseph Island is shown in Figure 1. We are aware that the date of a collection or a field observation cannot be taken as the first date that this orchid appeared in a given area. On the other hand, it is not possible to collect Helleborine anywhere until it has become established and is large enough to be noticed and correctly identified. It is known that, at least with some of our native orchids, this may involve a period of five to ten years. Since comparisons are only relative, the date of collection is still useful as a reference point in following the changes in size and shape of areas occupied by this species.

OCCURRENCES OUTSIDE ONTARIO

In order to comment on the direction and method of spread of Helleborine, it is essential to consider its occurrence in areas adjacent to Ontario. There is a review of the literature reporting the first discovery of Helleborine in the province of Quebec and several states from Massachusetts to Montana and south to Delaware (Doyon & Cayouette 1966). Also, distribution maps of *Epipactis helleborine* have appeared in various floras for states bordering the Great Lakes. We have not made personal searches in herbaria for collections from outside Ontario. We did write to curators of herbaria in the relevant states and the information received has been added to the base map of Southern Ontario (Figure 3). Our comments therefore, will be based on the information that has been obtained by correspondence and from the literature.

The first discovery of *Epipactis helleborine* in the province of Quebec has been attributed to N. D. Keith, who found it growing on Mt. Royal in 1892 (see Mousley 1927) and some botanists believe this to be the result of an escape from gardens. The species is said to have been planted by early colonists for its reputed medicinal properties (see Dalbis 1921). The occurrence of Helleborine in sixty-seven localities in Quebec was mapped by

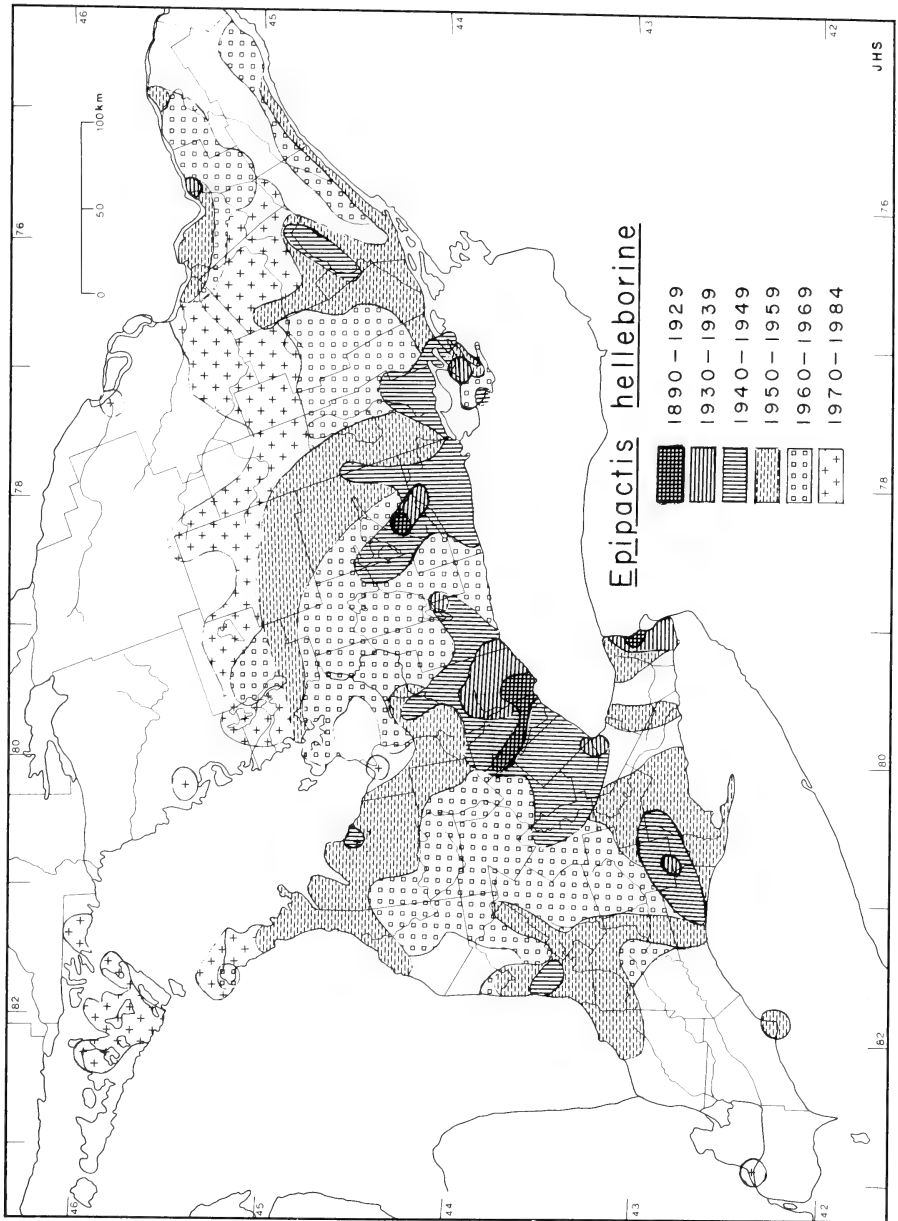


Fig. 5. Distribution of records for *Epipactis helleborine* in southern Ontario divided into time intervals to reflect the spread from 1890 to 1984.

Doyon & Cayouette (1966) and the clustering of sites around Montreal suggests this region as the most likely origin for the spread of the orchid into the lower part of the Ottawa valley. Actually, the first report for Ottawa was not until 1930 and it was much later before any sites for the plant were found in the easternmost part of Ontario between the Ottawa and St. Lawrence Rivers.

Doyon and Cayouette remarked that the northeastern limit of Helleborine in Quebec had not changed significantly in the twenty-six years between the observations of Marie-Victorin and Meilleur (1939) and their own herbarium survey (Doyon & Cayouette 1966). This would seem to support the suggestion by Rousseau (1968) that the northward migration of this orchid may be limited by local climatic factors, specifically, that the plant requires a growing season with not less than 2500 degree-days of heat.

Helleborine was first reported in North America from New York State, where it was discovered in 1879 growing in a woods near Syracuse (House 1933). In 1881 a second site was found near Canandaigua and a year later a third location turned up in the Buffalo area, close to the border of Ontario. The Buffalo site consisted of a well-established population (*ca* 200 plants) along a northerly hillside in Forest Lawn Cemetery, near Scajauquady's Creek (Zenkert 1949). Zenkert kept track of the population in that locality and found it was still flourishing 65 years later (September 1947). He also commented that some members of the Buffalo Naturalists' Club "... made it a practice to transplant live specimens of Helleborine from the Cemetery to outlying localities ..." (Zenkert 1949, p. 96).

Our series of maps plotted at 10-year intervals suggested that populations in the vicinity of Buffalo could well have been the source from which Helleborine migrated across the Niagara River into the eastern part of Ontario's Niagara Peninsula. On examining a copy of the distribution map on file in the herbarium of the New York State Museum (NYS), it is apparent that Helleborine is now found essentially throughout the state from Lake Erie to the Hudson River valley. It is abundant in the Finger Lakes region and in the areas bordering the southern and eastern shores of Lake Ontario. We have been informed that "... the species seems intuitively to be much more abundant in the Adirondacks than it appears to be from our records ... [and occurs] quite generally across the northern portion of the state ..." (C. J. Sheviak *pers. comm.*). Some of the records for New York State map have been added to Figure 4. The account published by House over fifty years ago (House 1933) covered a period of just over fifty years from the first discovery near Syracuse and included a map for New York State showing locations of records for Helleborine with dates of collection. We note that the dates for the sites around the eastern end of Lake Ontario range from 1927 to 1933. That part of the state could well have been the source for migration of the orchid to the Ontario side of the St. Lawrence River and the north shore of Lake Ontario as it was first found in Prince Edward County in 1930.

Helleborine is not as common in Pennsylvania as in New York State, judging from the most recent map we have seen (Wherry *et al.* 1979). The records are fairly numerous in the eastern half of the state but are less

abundant and more scattered westward, with only a few records shown near the south shore of Lake Erie.

For Ohio there are several collections just south of the Lake Erie shoreline, two of which were made in 1959 (R. L. Stuckey *pers. comm.*) but these may not be the earliest collections for the state. The locations of these collections fall outside the limits of our base map.

The occurrence of Helleborine in Michigan is, in part at least, the result of a deliberate introduction, by Ralph Ballard in 1891. Roots and seeds from near Buffalo were transplanted to the Niles area in Berrien County, which lies east of the southern end of Lake Michigan (see Voss 1972, p. 453; map 707). The map presented by Voss shows records for eight counties in the southern part of Michigan and two counties along the south shore of Lake Superior in the northern peninsula of Michigan. In discussing the occurrence of Helleborine in the vicinity of East Lansing, Drew and Giles (1951) suggested that the origin of the orchid in that area might have been the result of wind-borne seed carried from the Niles site (a distance of about 100 miles) by prevailing southwesterly winds. According to Voss (1972), Helleborine is spreading in Michigan and the populations on the west side of Lake Huron may be considered as possible sources for migration into the upper Lake Huron region, especially to St. Joseph, Drummond, and Cockburn Islands. Its appearance on the east half of Manitoulin and on other smaller islands nearby is assumed to be the result of migration from populations in the Bruce Peninsula and neighbouring parts of Ontario.

We have not seen any reports for the Lake Superior portion of Ontario nor for Manitoba or Minnesota. According to Szczawinski (1959), *Epipactis helleborine* is an introduction in British Columbia. His map had records from only the southern part of Vancouver Island and he stated that “. . . A number of people who introduced this plant into their gardens in Victoria have reason to regret it.” (Szczawinski 1959, p. 79).

DISCUSSION

The patterns of expansion in the various areas occupied by Helleborine in southern Ontario (Figure 5), suggest, in some cases at least, the most likely sources for its spread and the direction of migration. However, the apparent jumps to disjunct areas as in the first noted appearances at Ottawa and in the vicinity of Peterborough are difficult, if not impossible, to explain. When evidence of deliberate transplanting is lacking, we must assume natural or accidental introduction at these disjunct sites.

The various means by which Helleborine could become established in a new site may be divided into three categories, i.e., natural, deliberate, and accidental. The obvious natural means is dispersal of seed by wind and the direction of the wind can vary from day to day. Seed of Helleborine is exceedingly fine (almost microscopic in size), hence it is so light in weight that it could remain airborne long enough to be carried a great distance before falling. It is also possible for some of the seed that has fallen on the ground to

be washed away during heavy rains and carried by a stream or river to be deposited later on a flood plain or shore of the drainage system.

Since the roots of Helleborine are large when fully developed and may be found close to the soil surface or as deep as four to ten inches, it is hard to visualize natural spread by roots. Elongation with formation of new flowering stems is a possibility for very local increase and slow spread of populations. One method of dispersal by roots might be effected by the erosion of stream-banks due to seasonal or other flooding. This could cause a plant or part of its root system to be washed into the stream and transported to a new site.

Deliberate transplanting of native and introduced plants from one location to another is an established fact. Zenkert (1949) recorded transplanting of Helleborine as a common practice by naturalists in the Buffalo area. Unfortunately, records of such transplants are rarely published. Two such examples relevant to the spread of Helleborine in Ontario are known.

A resident of a subdivision of Sault Ste. Marie, Ontario, has reported transplanting Helleborine to his backyard ('miniwoodlot') from "... at least three populations, one from southern Ontario, one from Lennoxville, Quebec, and one from St. Joseph Island ..." (A. G. Gordon, *pers. comm.*) In some cases complete plants had been dug and moved, in others the tops of stems with seed capsules were taken and stuck in the ground or seed was simply scattered around. The orchid has become well established, with the number of individuals varying yearly from a few dozen to literally thousands in the backyard woodlot and other populations have been observed on neighbouring properties.

When informed of the recent collection of Helleborine on St. Joseph Island, Dr. Gordon commented "... with reference to Dan Brunton's [discovery] on St. Joseph Island, I must also confess that I now remember I had discovered a station there some years ago [i.e., before 1982] ... one or two woodlots in which they occur on St. Joseph Island ... I believe they are quite site specific, but in the mosaic of sites on St. Joseph Island, they will doubtless in time occupy all their niches ... "

We therefore conclude that Dr. Gordon's discovery of Helleborine on St. Joseph Island predates that of Brunton although no voucher specimen has been preserved in a herbarium. Future discoveries of new sites in the Sault Ste. Marie area may arise which could be the result of seed dispersal from the populations which developed from Dr. Gordon's transplants.

Another transplanting that may have resulted in the establishment of one or more populations of Helleborine in parts of northern Ontario was reported to the senior author some years ago. A large plant of Helleborine (three feet tall) was transplanted by a Toronto naturalist in 1957 to the west side of the Groundhog River north of the Timmins Highway. Seeds of this species were spread around in the same area (D. L. Robb, *pers. comm.*). The location of the site was given in some detail and, in view of the recent report of Helleborine in the Timiskaming District, an investigation of this transplant site might be worth undertaking.

Accidental transfer of seeds or, perhaps less commonly, of roots could occur during removal of other plants from a location in the wild to a garden, woodlot, or other site. The soil taken with the transplanted specimen might contain seeds, seedlings or roots of Helleborine, depending on the location of the area from which the specimen was taken. Similarly, the removal of woodland or other soils for use in enriching home or country gardens could effect a transfer of propagules from one area to another.

The accidental occurrence of Helleborine in an Ottawa garden has been reported, followed by an account of its reappearance in the same garden (after removal of mature plants) at intervals of four and eight years (Dore 1968, 1977). Dr. Dore classed Helleborine as an insidious weed which should be eliminated from our flora but was not able to suggest a method for doing so.

CONCLUSION

Whether Helleborine is actually considered a weed or not may be a matter of choice on the part of the beholder. But there is no doubt, from the history of its spread in North America to date, that it is a very aggressive plant. The evidence presented here supports this view. As we can expect to see further spreading, attention should be concentrated on the current gaps in its known distribution and on the fringe areas to the north and west, especially along the north shore of Lake Huron and Lake Superior in the vicinity of Sault Ste. Marie.

We would appreciate receiving additional records for the occurrence of Helleborine in any part of the Great Lakes Region. Information submitted should include date of collection (or of a field observation or first discovery) and exact location in the form of latitude and longitude (or map number and UTM Grid Reference for maps in the Canadian Topographic Series). Such records will be put on file in the National Herbarium (CAN) and kept available for any future updating of the distribution of this species.

ACKNOWLEDGMENTS

We wish to thank all those who have contributed records and other information used in this study. In particular, we thank Dr. P. F. Maycock, Erindale College, who made available his private herbarium and files which contained species lists for hundreds of sites that he has examined during the course of ecological studies throughout Ontario. Records from the Native Orchid Location Survey were provided in the 1970s by E. W. Greenwood, who also reported his finds on Manitoulin Island. Dr. J. K. Morton sent records from his personal herbarium and from that of the University of Waterloo (WAT), as well as data for Manitoulin and other islands in Lake Huron. Mr. R. E. Whiting of Weston provided sight records from the Muskoka District and other areas. Jean Williamson of Mindemoya reported her sightings from Manitoulin Island and F. W. Schueler, National Museum of Natural Sciences, Ottawa, gave us records of sightings on the islands off the tip of the Bruce Peninsula. Joyce Reddoch kindly provided us with a copy of the section on Helleborine in a manuscript by Allan Reddoch and herself entitled "Orchids in the Ottawa District". A map showing locations of collections in New York State

was kindly sent to us by Dr. C. J. Sheviak, New York State Museum (NYS), Albany. The locations for the two Michigan records shown in Figure 4 were determined by John Freudenstein and kindly forwarded by Dr. E. G. Voss from the University of Michigan Herbarium (MICH).

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REVIEW

OHIO ENDANGERED AND THREATENED VASCULAR PLANTS. Eds. Robert M. McCance, Jr. and James F. Burns. Ohio Department of Natural Resources, Columbus, Ohio. Available from Publications Center, Ohio Department of Natural Resources, Fountain Square, Columbus, Ohio 43224. \$15.00 + \$2.25 postage and handling.

This reference work presents a great deal of information, in a readily useable fashion, on all of Ohio's endangered and threatened vascular plants. The brief introduction gives the scope and purpose of the book, history of work on Ohio rare plants, rare plant distribution in Ohio, and causes of plant rarity in Ohio. The data are presented in the form of abstracts, usually one or two pages long, for each species. A total of 367 species are treated, 182 considered endangered and 185, threatened. Each abstract contains a distribution map for Ohio, coded for pre- and post- 1960 records, synonyms in wide use, plant habit, discussions of similar species, listing of the overall range of the species, status in Ohio, whether threatened or endangered, Ohio habitats, hazards to the species, recovery potential, guidelines for documenting the species occurrence (i.e., avoid collecting roots, need mature fruit, etc.), and a section including more general comments. In short, the abstracts theoretically contain all the information that one needs to know to understand a species' predicament in Ohio and its potential for future survival. Tremendous amounts of data are summarized in these abstracts and the compilation must have been an enormous task. An attempt evidently was made to update nomenclature and taxonomy, but consistency was not achieved. Recent work on generic delimitation in *Arenaria* and related genera was not followed, but Ohio orchids formerly placed in *Habenaria* are here put in *Platanthera*. Nomenclature and taxonomy are updated in *Wolffia*, and *Juncus alpinus* is called *J. alpinoarticulatus* (based on a weak nomenclatural argument at best), but an evidently simple case for a prior name for *Baptisia leucantha* is ignored. Comments about the recovery potential of species are largely speculative and undoubtedly open to dispute. They are usually based on the adaptability of the plants to disturbance, the capacity of the species for spread by seed or vegetative means, and the capability of the species to invade new habitats. Much research would be needed to test these comments, but they provide a foundation on which to build.

For Michigan readers, it may come as a surprise to see many of our widespread and common species listed. Examples include *Potamogeton natans*, *P. richardsonii*, *Carex aquatilis*, *Salix petiolaris*, *Actaea rubra*, and *Potentilla palustris*. Nearly one third of Ohio's endangered and threatened species are plants of bogs, fens, and aquatic habitats. This provides a clear statement about the sensitivity of these wetland species to drainage, pollution, and other threats and hopefully will serve as a warning to other areas.

After the abstracts, there are appendices listing Ohio Plants of Federal concern, Ohio legislation covering rare plants and collecting permits, guidelines for labelling collections of rare plants, notes about Ohio data search services, and county listings of rare plants by abstract number.

This is a very thorough account containing a great deal of useful information. Indeed, for Ohio rare plants it is encyclopedic. Anybody interested in endangered and threatened species, species management, and environmental restoration will find much of use in this book—as will people interested in the flora of the Great Lakes region in general. The modest price makes this book an excellent buy.

—A. A. Reznicek

REVIEW

THE VASCULAR PLANT FLORA OF PEEL COUNTY, ONTARIO. By Jocelyn M. Webber. 1984. v + 94 pp. Botany Press, 90 Wolfrey Ave., Toronto, Ontario, M4K 1K8. \$10.00 CAN.

Although of local scope, this book warrants a brief review because its accuracy, attention to detail, and convenient format make it a useful and excellent model for other studies of its kind.

Concise but informative introductory notes outlining the physical environment, the phytogeography and vegetation, and the history of botanical studies in Peel county as well as the methodology employed in this study set the stage for the treatment. The body of the book is an annotated checklist of the vascular plants, including the scientific name, relevant synonyms, the common name—if one exists, and comments on the habitat and occurrence of each species. For every species, presence in each of the five townships comprising Peel County is noted and an overall abundance code, from 0 to 4 is given; 0 being extinct and 4 being more than 40 stations. A total of 1334 species are listed. Peel County is one of the most urbanized in Ontario, and the statistics of the flora reflect this. About 10% of the flora is listed as extinct. For the Orchidaceae, I counted 11 out of 23 species, nearly 50%, listed as extinct in the county.

Much effort has gone into updating the nomenclature and taxonomy, as evidenced by the extensive bibliography of nearly 100 references. Indeed, this book is useful for the extensive reference list alone. The text has very few typographical and other errors.

This book should be owned by anyone considering a floristic study of a county or other small area.

—A. A. Reznicek

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**ENDANGERED AND THREATENED VASCULAR PLANTS IN
 MICHIGAN. II. THIRD BIENNIAL REVIEW
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This list embodies recommendations by the Technical Advisory Committee for Plants (J. H. Beaman, Chairman, other members the co-authors) of the Michigan Department of Natural Resources (DNR) Endangered Species Program. It is the second substantive revision of the original list published by Wagner et al. (1977). A review of past and present activities concerning endangered and threatened plants in Michigan is provided as a precursor to the list.

LEGISLATION, DEFINITIONS, AND CRITERIA

The Michigan Endangered Species Act of 1974, Act No. 203, amended 1982, Act No. 404, Sec. 4, states that the Director of the DNR "... shall

¹Publication of this report is authorized by the Michigan Department of Natural Resources. We thank Dr. Leni A. Wilsmann for administering Committee activities during the third biennial review. We also acknowledge with much gratitude the contributions to the Endangered Species Program by Dr. Sylvia M. Taylor, who served for eight years as its Coordinator. Progress with the issues of endangered and threatened species recognition and preservation in Michigan during this period is due in large part to her dedicated efforts.

The current Michigan endangered species list and law, rationale for proposed changes, and other Program information are available from: Endangered Species Coordinator, Wildlife Division, Department of Natural Resources, Stevens T. Mason Building, P. O. Box 30028, Lansing, MI 48909.

conduct investigations on fish, plants, and wildlife in order to develop information relating to population, distribution, habitat needs, limiting factors, and other biological and ecological data to determine management measures necessary for their continued ability to sustain themselves successfully. On the basis of these determinations and other available scientific and commercial data, which may include consultation with scientists and others who may have specialized knowledge, learning, or experience, the [Natural Resources] commission shall promulgate a rule listing those species of fish, plants, and wildlife which are determined to be endangered or threatened within the state” The Act also directs that “The commission shall conduct a review of the state list of endangered and threatened species within not more than 2 years after its effective date and every 2 years thereafter, and may amend the list by appropriate additions or deletions”

An endangered species is defined by the Act as “. . . any species of fish, plant life, or wildlife which is in danger of extinction throughout all or a significant part of its range” A threatened species “. . . means any species which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range.” In terms of protection accorded endangered and threatened species, the difference is that taking (to take is defined as to collect, pick, cut, dig up, or destroy in any manner) of a threatened species is not prohibited when the Natural Resources Commission has determined that its abundance in the state justifies a controlled harvest not in violation of federal laws or regulations. These categories are further defined by the DNR (undated brochure) as follows:

The state list of “endangered” species will be those species listed by the Secretary of Interior as endangered and resident in any part of their life cycle in Michigan. It will also include those indigenous species which the State of Michigan feels should be included on the national list of endangered species because they are on the verge of extinction. The definition refers to worldwide status of a species. Also, it recognizes subspecies of fish or wildlife, or plant life, or lower taxa in a common spatial arrangement, that reproduce and represent a truly unique, identifiable form.

The state list of “threatened” species includes those species, and lower taxa as defined under endangered, that are threatened with extirpation in Michigan. For the purposes of state law, the Michigan range is considered significant except when the state portion of the range is considered to be peripheral. Peripheral species will not be listed as “threatened” unless their populations are also threatened in their primary range outside of Michigan. Species whose range is now reduced to a relatively few isolated populations that do not interbreed are included within this definition, as are species which were once extirpated, but are now in the process of becoming reestablished through introductions.

In the previously published list a category of taxa considered rare was included. These taxa are not accorded formal protection under the Act, but “rare or scarce” species have been defined by the DNR (undated brochure) as follows:

A species or lower taxon that while not “endangered” or “threatened”, is extremely uncommon in Michigan and deserves further study and monitoring. Peripheral species, not listed as “threatened” may be included in this category along with those species which were once “threatened” or “endangered” but now have increasing or protected, stable populations.

At the time of preparation of the list of plants for the second biennial review the category of "rare" was renamed "special concern." In the present list we continue to use the "special concern" designation.

Criteria used to develop the first list were outlined by Wagner et al. (1977); see also Beaman (1977). These can now be more explicitly stated as follows:

Criteria for endangered:

Extreme rarity in Michigan (one or two known viable populations) *and* at least one of the following conditions:

1. Endemism or near-endemism to Michigan; *or*
2. Rarity throughout North America; *or*
3. Rarity in the Great Lakes Region with demonstrable threat to state populations; *or*
4. Special factors causing unusual vulnerability (e.g., disease, highly specialized requirements, exceptional danger of exploitation).

The following definitions may serve to clarify these criteria:

Rarity: nowhere common; limits given on numbers of populations are guidelines only and are not intended to be rigid, artificial cut-offs.

Viable population: an actively reproducing population large enough to maintain itself indefinitely in a natural community with minimal disturbance.

Criteria for threatened:

- A. Extreme rarity in Michigan, but not meeting secondary endangerment criteria; *or*
- B. Endemism or near-endemism to Michigan; *or*
- C. State rarity (10 or fewer known viable populations, or if no current population data are available, occurrence in five or fewer counties and 20 or fewer collection localities with known decline) *and* at least one of the following:
 1. rarity in the Great Lakes region; *or*
 2. demonstrable threat to all or most state populations; *or*
 3. disjunction of phytogeographic significance; *or*
 4. unusual habitat vulnerability (e.g., prairie, fen, lakeshore); *or*
 5. extremely localized state distribution (one or two counties); *or*
 6. special factors (scientific importance, absence of recent records); *or*
- D. No populations known extant or recently reported.

DEVELOPMENT OF THE LIST

Michigan was one of the first states to initiate an endangered species program following the 1973 federal Endangered Species Act. The state list of endangered and threatened species, which is now in its third review, reflects the considerable progress that has been made in understanding the status of endangered and threatened plants in Michigan. Of particular importance was

the establishment in 1980 of the Michigan Natural Features Inventory by The Nature Conservancy, under contract with the DNR. One of the most important tasks of the Inventory has been to develop a detailed data base on the statewide status of endangered, threatened, and other species and plant communities of special concern in the state. The Natural Features Inventory has routinely conducted intensive field searches and studies of species listed or being considered for listing. Additionally, grants from the Michigan Living Resources Program and the U.S. Fish and Wildlife Service have permitted special investigations of certain species. As a result of these activities, the species list submitted for the third biennial review has a considerably stronger scientific basis than could be marshalled previously. A book describing the endangered and threatened species of Michigan and discussing their status is in preparation by the Natural Features Inventory.

Several DNR divisions are involved in endangered and threatened species activities.² The Endangered Species Program is administered by the Wildlife Division and provisions of the Act are enforced by the Law Enforcement Division. The Land Resource Programs Division and the Wildlife Division assist in providing biological survey information through support to the Natural Features Inventory.

The list review process involves scientists, the general public, and various governmental agencies. The DNR uses technical advisory committees to develop the endangered and threatened species list for major groups of organisms. Plants and animals proposed for listing by the technical committees are reviewed by the Endangered Species Coordinator, by an Endangered Species Citizens' Advisory Committee, by the Natural Resources Commission, the Attorney General, the Joint Legislative Committee on Administrative Rules, and finally again by the Natural Resources Commission. A public hearing is held at the beginning of the Administrative Rules procedure.

The first list, with one threatened and 16 endangered plants, was filed with the Secretary of State on November 18, 1976, and became effective

²Other legislation, both state and federal, provides additional protection for Michigan's flora. State legislation known as the "Christmas Tree Law" (Act 182, Public Acts of 1962) provides protection from harvest without consent of the landowner for certain plants, including all trees, shrubs, vines, orchids, trilliums, gentians, club-mosses, North American lotus, birdfoot violet, trailing arbutus, and pipsissewa. The federal Endangered Species Act (Public Law 93-205, as amended in 1982) protects species on the United States list. The amended federal Act now prescribes a rigorous listing process for endangered and threatened species, imposing a one-year deadline for publication of a proposed rule. Final listing action must occur within one year of rule publication. Prior, less rigorous legislation resulted in the mandatory withdrawal in 1979 of approximately 1700 plant taxa proposed for review in 1976. Currently, the federal plant list contains 72 endangered species, 11 threatened species, and 36 proposed for listing [*Endangered Species Technical Bulletin* 10(1):12]. Only one species that occurs in Michigan, *Isotria medeoloides* (smaller whorled pogonia), is now on the federal list [*Federal Register* 47(176), Sept. 10, 1982]. However, there are currently 15 candidates for federal listing that occur in Michigan.

It should be recognized that protection is extended only to indigenous occurrences of endangered and threatened species. Such things as chestnut trees planted on the west side of the state or *Wisteria frutescens* on a porch trellis are not covered.

December 2, 1976. The rest of the initial list of threatened plant species was so long (197 taxa) that documentation and review could not be completed in 1976. The first biennial review of the list was initiated at the December, 1978, Commission meeting. The list from that review, which became effective February 5, 1980, included threatened as well as endangered species. The second biennial review, which took place in 1982, resulted in four species changed from threatened to endangered status, four from endangered to threatened, one added as endangered, 28 added as threatened, and 24 delisted. The resultant list, which became effective February 24, 1983, and will remain in effect until completion of the current review process, includes 13 endangered and 200 threatened taxa, and 24 thought to be extirpated in Michigan.

THE PROPOSED LIST

The present revision proposes to add one species as endangered and 13 as threatened; six species are deleted as threatened and placed as special concern; 12 species are deleted as threatened and listed as probably extirpated; one species not previously listed is added to the latter category; one species and one variety previously listed as threatened and one species previously listed as probably extirpated are deleted entirely; several nomenclatural and taxonomic changes are made, with relevant synonyms indicated in brackets.

Reasons for revision of the list include: 1) nomenclatural and taxonomic changes resulting from improved understanding of certain taxa, 2) discovery of species not previously known from the state, 3) investigations which indicate that species have been extirpated from the state (should they be rediscovered, such species would automatically be listed as threatened), 4) data that show species to be either rarer or less rare than previously thought, and 5) other factors taken into consideration in application of the criteria stated above. The data base assembled by the Natural Features Inventory over the past five years, data for Part II of *Michigan Flora*—Dicotyledons, through Cornaceae (Engler and Prantl sequence) by E. G. Voss (now in press), and personal knowledge of members of the Technical Advisory Committee have been used in making the revisions for this new list.

Because of the biennial review process, the Technical Advisory Committee for Plants has a continuing function in the development of information about uncommon species in the state. Committee members will be pleased to hear from anyone concerning listed, proposed, or potential candidate species or the general problem of endangered species in Michigan. Concern may also be directed to the DNR Endangered Species Program, the Natural Features Inventory, the Rare Plants Committee of the Michigan Botanical Club, and the Endangered and Threatened Species Committee of the Michigan Natural Areas Council.

A primary reason for publishing this list is to solicit information from knowledgeable persons and to encourage monitoring of the status of species by anyone interested in Michigan plants. The current review period encom-

passes one field season to allow time for new data to be collected on species proposed for status changes, species of questionable status, or species overlooked by the Technical Committee. The candidate list will be finalized by the Committee in Fall, 1985, prior to the public hearing and submission of the list to the Legislature. When commenting on the status of a particular species, reference should be made to the criteria and definitions provided above. Documentation in the form of photographs or specimens that can be critically examined is also essential. Identification and protection of areas where listed species occur is one of the most important mechanisms for preserving these species. The fact that 36 plant species are now thought to be extirpated in Michigan should direct public attention to the need for serious concern about our native flora.

Four lists are provided below, comprising endangered species (14), threatened species (193), species probably extirpated (36), and species of special concern (109). Within each list the taxonomic order is pteridophytes, monocotyledons, and dicotyledons. Under these categories the taxa are listed alphabetically by family, genus, and species. Names in bold face are taxa newly proposed to be added. Those in braces ({ }) are proposed deletions. Common names are provided when possible, but it should be noted that such names can refer to more than one species, and a particular species may have more than one common name. Especially problematical are genera in which several or all species have the same common name, in which case the common name is usually omitted (e.g. *Carex*). An asterisk (*) preceding the scientific name indicates that more than one infraspecific taxon of the species occurs in Michigan, but only the taxon indicated has status on the list. At the time of writing, the new list has undergone only initial screening by the Natural Resources Commission. It is presented as a candidate list; proposed changes lack official status. Endangered and threatened species on the 1983 list are of course currently protected.

ENDANGERED

PTERIDOPHYTES

LYCOPODIACEAE (Club-moss Family)

Lycopodium sabinifolium Willd., Savin-leaved club-moss.

POLYPODIACEAE (Fern Family)

Phyllitis scolopendrium var. *americana* Fern., Hart's-tongue fern.

MONOCOTYLEDONS

CYPERACEAE (Sedge Family)

Eleocharis atropurpurea (Retz.) Kunth, Purple spike-rush.

Scirpus hallii Gray, Hall's bullrush.

Scleria reticularis Michaux, Nut-rush.

LILIACEAE (Lily Family)

**Polygonatum biflorum* var. *melleum* (Farwell) Ownbey, Solomon-seal.

ORCHIDACEAE (Orchid Family)

Habenaria leucophaea (Nutt.) Gray, Prairie fringed orchid.

Isotria medeoloides (Pursh) Raf., Smaller whorled pogonia.

Orchis rotundifolia Pursh, Small round-leaved orchis.

DICOTYLEDONS

FAGACEAE (Beech Family)

Castanea dentata (Marsh.) Borkh., American chestnut.

HALORAGACEAE (Water-Milfoil Family)

Proserpinaca pectinata Lam., Mermaid-weed.

LENTIBULARIACEAE (Bladderwort Family)

Utricularia inflata Walter [*U. radiata* Small], Floating bladderwort.

ROSACEAE (Rose Family)

Chamaerhodos nuttallii var. *keweenawensis* Fern., no common name.

SCROPHULARIACEAE (Figwort Family)

Chelone obliqua L., Purple turtlehead.

THREATENED

PTERIDOPHYTES

LYCOPODIACEAE (Club-moss Family)

Lycopodium appressum Lloyd & Underwood, no common name.

OPHIOGLOSSACEAE (Adder's-tongue Family)

Ophioglossum [vulgatum var.] pycnostichum (Fern.) Löve & Löve, Southeastern adder's tongue.

POLYPODIACEAE (Fern Family)

Asplenium ruta-muraria L., Wall-rue.

Cryptogramma acrostichoides R. Br., American rock-brake.

Dryopteris celsa (Wm. Palmer) Small, Log fern.

D. filix-mas (L.) Schott, Male fern.

Pellaea atropurpurea (L.) Link, Purple cliff-brake.

Woodsia alpina (Bolton) S. F. Gray, Northern woodsia.

W. obtusa (Sprengel) Torrey, Blunt-lobed woodsia.

SCHIZAEACEAE (Curly-grass Family)

Lygodium palmatum (Bernh.) Sw., Climbing fern.

MONOCOTYLEDONS

ALISMATACEAE (Water-plantain Family)

Sagittaria montevidensis Cham. & Schlecht, Arrowhead.

{COMMELINACEAE (Spiderwort Family)}

{*Tradescantia bracteata* Small, Spiderwort.}

CYPERACEAE (Sedge Family)

Carex assiniboinensis W. Boott, no common name.

C. atratiformis Britton, no common name.

- C. crus-corvi* Kunze, no common name.
{*C. decomposita* Muhl., no common name.}
C. heleonastes Ehrh., no common name.
C. media R. Br., no common name.
C. nigra (L.) Reich., no common name.
C. platyphylla Carey, no common name.
C. rossii Boott, no common name.
C. scirpoidea Michaux, no common name.
C. seorsa Howe, no common name.
C. synchocephala Carey, no common name.
C. typhina Michaux, no common name.
C. wiegandii Mackenzie, no common name.
Eleocharis caribaea (Rottb.) S. F. Blake, no common name.
E. compressa Sulliv., Flattened spike-rush.
E. melanocarpa Torrey, Black-fruited spike-rush.
E. nitida Fern., Slender spike-rush.
E. parvula (R. & S.) Link, no common name.
{*E. radicans* (Poiret) Kunth, no common name.}
Fimbristylis puberula (Michaux) Vahl, no common name.
Fuirena squarrosa Michaux, Umbrella-grass.
Psilocarya scirpoides Torrey, Bald-rush.
Scirpus olneyi Gray, no common name.
{*Scleria pauciflora* Willd., no common name.}

IRIDACEAE (Iris Family)

- Iris lacustris* Nutt., Dwarf lake iris.
Sisyrinchium atlanticum Bickn., Atlantic blue-eyed-grass.

JUNCACEAE (Rush Family)

- Juncus brachycarpus* Engelm., no common name.
J. militaris Bigelow, Bayonet rush.
J. scirpoides Lam., no common name.
J. stygius L., no common name.
J. vaseyi Engelm., no common name.
Luzula parviflora (Ehrh.) Desv., no common name.

LEMNACEAE (Duckweed Family)

- Lemna valdiviana* Phil., no common name.

LILIACEAE (Lily Family)

- Allium schoenoprasum* L., Wild chives.
Camassia scilloides (Raf.) Cory, Wild-hyacinth.
Disporum hookeri (Torrey) Nicholson, Fairy bells.
Tofieldia pusilla (Michaux) Pers., False asphodel.
Trillium nivale Riddell, Snow trillium.
T. recurvatum Beck, no common name.
T. sessile L., Toadshade.
T. undulatum Willd., Painted trillium.
{*T. viride* Beck, no common name.}

ORCHIDACEAE (Orchid Family)

- Calypso bulbosa* (L.) Oakes, Calypso or fairy-slipper.
Cypripedium candidum Willd., White lady-slipper.
Habenaria ciliaris (L.) R. Br., Orange fringed orchid.
H. unalascensis (Sprengel) S. Wats., Alaska orchid.
Spiranthes ovalis Lindley, Lesser ladies' tresses.
S. tuberosa Raf., Little ladies' tresses.
Tipularia discolor (Pursh) Nutt., Crane-fly orchid.
Triphora trianthophora (Sw.) Rydb., Nodding pogonia or three-birds orchid.

POACEAE (Grass Family)

- {*Aristida dichotoma* Michaux, no common name.}
- A. longispica* Poirét, no common name.
- A. necopina* Shinnars, no common name.
- Beckmannia syzigachne* (Steudel) Fern., Slough grass.
- Bouteloua curtipendula* (Michaux) Torrey, Side-oats grama.
- Bromus pumpellianus* Scribner, no common name.
- Calamagrostis lacustris* (Kearney) Nash, no common name.
- C. stricta* (Timm) Koeler, no common name.
- Diarrhena americana* Beauv., no common name.
- Festuca scabrella* Torrey, Rough fescue.
- Glyceria acutiflora* Torrey, no common name.
- Muhlenbergia richardsonis* (Trin.) Rydb., Mat muhly.
- {*Oryzopsis canadensis* (Poirét) Torrey, Canada rice-grass.}
- Panicum leibergii* (Vasey) Scribner, no common name.
- P. spretum* Schultes, no common name.
- {*P. verrucosum* Muhl., no common name.}
- {*Phleum alpinum* L., Mountain timothy.}
- Poa alpina* L., Alpine bluegrass.
- P. canbyi* (Scribner) Piper, no common name.
- P. paludigena*** Fern. & Wieg., Bog bluegrass.
- Sporobolus heterolepis* (Gray) Gray, Prairie dropseed.
- {*Stipa comata* Trin. & Rupr., no common name.}
- {*Triplasis purpurea* (Walter) Chapman, Sand grass.}
- Uniola latifolia* Michaux, Wild-oats.
- **Zizania aquatica* L. var. *aquatica*, Wild-rice.
- {*Z. aquatica* var. *interior* Fassett, Wild-rice.}

POTAMOGETONACEAE (Pondweed Family)

- Potamogeton bicipulatus* Fern. [*P. capillaceus* Poirét], no common name.
- P. confervoides* Reichenb., no common name.
- P. hillii* Morong, no common name.
- P. pulcher* Tuckerman, no common name.
- P. vaseyi* Robbins, no common name.

RUPPIACEAE (Ditch-grass Family)

- Ruppia maritima* L., Ditch-grass or widgeon-grass.

DICOTYLEDONS

ACANTHACEAE (Acanthus Family)

- Justicia americana* (L.) Vahl, Water-willow.
- Ruellia humilis* Nutt., no common name.
- R. strepens* L., no common name.

APIACEAE (Parsley Family)

- Berula pusilla* (Nutt.) Fern., no common name.
- Eryngium yuccifolium* Michaux, Rattlesnake-master or button-snakeroot.
- Zizia aptera*** (Gray) Fern., Prairie golden alexanders.

ARALIACEAE (Ginseng Family)

- Oplopanax horridus* (Sm.) Miq., Devil's club.
- Panax quinquefolius* L., Ginseng.

ARISTOLOCHIACEAE (Birthwort Family)

- Aristolochia serpentaria* L., Virginia snakeroot.

ASCLEPIADACEAE (Milkweed Family)

Asclepias hirtella (Pennell) Woodson, no common name.

A. ovalifolia Dcne., no common name.

A. sullivantii Engelm., no common name.

ASTERACEAE (Composite Family)

Agoseris glauca (Pursh) Raf., no common name.

Antennaria rosea Greene, no common name.

Arnica cordifolia Hooker [*A. whitneyi* Fern.], Heart-leaved arnica.

Aster modestus Lindley, no common name.

Aster sericeus Vent., Western silvery aster.

Cacalia plantaginea (Raf.) Shinnars [*C. tuberosa* Nutt.], Prairie Indian plantain.

Cirsium pitcheri (Torrey) Torrey & Gray, Pitcher's thistle.

Coreopsis palmata Nutt., no common name.

Erigeron hyssopifolius Michaux, no common name.

Eupatorium sessilifolium L., Upland boneset.

{*Helianthus microcephalus* Torrey & Gray, no common name.}

H. mollis Lam., Downy sunflower.

Lactuca pulchella (Pursh) DC., Blue lettuce.

Petasites sagittatus (Pursh) Gray, Sweet coltsfoot.

{*Polymnia uvedalia* L., Leafcup.}

Senecio indecorus Greene, no common name.

Silphium integrifolium Michaux, Rosinweed.

S. laciniatum L., Compass-plant.

S. perfoliatum L., Cup-plant.

Solidago houghtonii Torrey & Gray, Houghton's goldenrod.

{*S. lepida* DC., Goldenrod.}

{*S. remota* (Greene) Friesner [distinct from *S. tenuifolia* Pursh?], Goldenrod.}

Tanacetum huronense Nutt., Lake Huron tansy.

BORAGINACEAE (Borage Family)

Mertensia virginica (L.) Pers., Bluebells.

BRASSICACEAE (Mustard Family)

Arabis perstellata Braun, no common name.

Armoracia aquatica (Eaton) Wiegand, Lake-cress.

Braya humilis (C. A. Meyer) Robinson, no common name.

Dentaria maxima Nutt., Large toothwort.

Draba arabisans Michaux, no common name.

D. cana Rydb., no common name.

D. incana L., no common name.

Subularia aquatica L., Awlwort.

CACTACEAE (Cactus Family)

Opuntia fragilis (Nutt.) Haw., Fragile prickly-pear.

CAPRIFOLIACEAE (Honeysuckle Family)

Lonicera involucrata (Richardson) Banks, no common name.

{*Viburnum edule* (Michaux) Raf., Squashberry or Mooseberry.}

CARYOPHYLLACEAE (Pink Family)

Arenaria macrophylla Hooker, Sandwort.

Sagina nodosa (L.) Fenzl, Pearlwort.

Silene stellata (L.) Ait. f., Starry campion.

{*Silene virginica* L., Fire pink.}

Stellaria crassifolia Ehrh., no common name.

CISTACEAE (Rockrose Family)

Lechea pulchella Raf. [*L. leggettii* Britton & Hollick], Leggett's pinweed.

EMPETRACEAE (Crowberry Family)

Empetrum nigrum L., Black crowberry.

ERICACEAE (Heath Family)

Pterospora andromedea Nutt., Pine-drops.

Vaccinium cespitosum Michaux, Dwarf bilberry.

V. uliginosum L., Alpine blueberry.

FABACEAE (Legume Family)

Baptisia lactea (Raf.) Thieret [*B. leucantha* Torrey & Gray], White or prairie false indigo.

Dalea purpurea Vent. [*Petalostemon purpureum* (Vent.) Rydb.], Red prairie clover.

Hedysarum alpinum L., Alpine sainfoin.

Wisteria frutescens (L.) Poiret, Wisteria.

FUMARIACEAE (Fumitory Family)

Corydalis flavula (Raf.) DC., Yellow fumewort.

GENTIANACEAE (Gentian Family)

Bartonia paniculata (Michx.) Muhl., Panicked screw-stem.

Gentiana alba Muhl. [*G. flavida* Gray], Yellowish gentian.

G. linearis Froel., Closed gentian.

Sabatia angularis (L.) Pursh, Rose-pink.

HALORAGACEAE (Water-milfoil Family)

Myriophyllum farwellii Morong, no common name.

HYDROPHYLLACEAE (Waterleaf Family)

Phacelia franklinii (R. Br.) Gray, no common name.

LAMIACEAE (Mint Family)

Scutellaria elliptica Muhl., Hairy skullcap.

Trichostema brachiatum L. [*Isanthus brachiatus* (L.) BSP.], False pennyroyal.

T. dichotomum L., Bastard pennyroyal.

{LENTIBULARIACEAE (Bladderwort Family)}

{*Pinguicula vulgaris* L., Butterwort.}

NYMPHAEACEAE (Water-lily Family)

Nelumbo lutea (Willd.) Pers. [*N. pentapetala* (Walter) Fern.], American lotus.

Nuphar pumila (Timm) DC. [*N. microphylla* (Pers.) Fern.], Yellow pond-lily.

Nymphaea tetragona Georgi, Water-lily.

ONAGRACEAE (Evening-primrose Family)

Ludwigia alternifolia L., Seedbox.

L. sphaerocarpa Ell., no common name.

OROBANCHACEAE (Broom-rape Family)

Orobanche fasciculata Nutt., Broom-rape.

POLEMONACEAE (Phlox Family)

Phlox bifida Beck, Cleft phlox.

P. maculata L., Wild sweet William or Spotted phlox.

Polemonium reptans L., Jacob's ladder or Greek-valerian.

POLYGALACEAE (Milkwort Family)

Polygala incarnata L., Pink milkwort.

POLYGONACEAE (Buckwheat Family)

Polygonum careyi Olney, no common name.

Polygonum viviparum L., Alpine bistort.

PRIMULACEAE (Primrose Family)

Dodecatheon meadia L., Shooting-star.

RANUNCULACEAE (Crowfoot Family)

Hydrastis canadensis L., Golden-seal.

Ranunculus ambigens S. Wats., Spearwort.

R. cymbalaria Pursh, Seaside Crowfoot.

R. lapponicus L., Lapland buttercup.

R. macounii Britton, no common name.

R. rhomboideus Goldie, Prairie buttercup.

Thalictrum revolutum DC., Waxy meadow-rue.

T. venulosum Trel. [*T. confine* Fern.], no common name.

RHAMNACEAE (Buckthorn Family)

Ceanothus sanguineus Pursh, Wild-lilac.

ROSACEAE (Rose Family)

Dalibarda repens L., False-violet.

Filipendula rubra (Hill) Robinson, Queen-of-the-prairie.

Geum triflorum Pursh, Prairie-smoke.

Porteranthus trifoliatus (L.) Britton [*Gillenia trifoliata* (L.) Moench], Bowman's root.

Potentilla pensylvanica L., Cinquefoil.

Rubus acaulis Michaux, Dwarf raspberry.

Sanguisorba canadensis L., Canadian burnet.

SALICACEAE (Willow Family)

Populus heterophylla L., Swamp or black cottonwood.

Salix planifolia Pursh, Tea-leaved willow.

SARRACENIACEAE (Pitcher-plant Family)

**Sarracenia purpurea* f. *heterophylla* (Eaton) Fern., Pitcher-plant.

SAXIFRAGACEAE (Saxifrage Family)

Saxifraga paniculata Miller [*S. aizoon* Jacq.], Encrusted saxifrage.

S. tricuspidata Rottb., Saxifrage.

SCROPHULARIACEAE (Figwort Family)

{*Agalinis gattereri* (Small) Small [*Gerardia gattereri* Small], *Gerardia*.}

Besseyia bullii (Eaton) Rydb., Kitten-tails.

Castilleja septentrionalis Lindley, Pale Indian paintbrush.

Collinsia parviflora Douglas ex Lindley, no common name.

Euphrasia arctica Lange (sens. lat.), Eyebright.

Gratiola lutea Raf. [*G. aurea* Muhl.], Hedge-hyssop.

Mimulus alatus Aiton, Monkey-flower.

**Mimulus glabratus* var. *michiganensis* (Pennell) Fassett, Michigan monkey-flower.

VALERIANACEAE (Valerian Family)

Valeriana ciliata Torrey & Gray, Valerian.

Valerianella chenopodifolia (Pursh) DC., no common name.

VIOLACEAE (Violet Family)

- Viola epipsila* Ledeb., Northern marsh violet.
V. pedatifida G. Don, Prairie bird's-foot violet.

PROBABLY EXTIRPATED

PTERIDOPHYTES

EQUISETACEAE (Horsetail Family)

- Equisetum telmateia* Ehrh., Giant horsetail.

POLYPODIACEAE (Fern Family)

- Asplenium montanum* Willd., Mountain spleenwort.
Woodwardia areolata (L.) Moore, Netted chain fern.

MONOCOTYLEDONS

ALISMATACEAE (Water-plantain Family)

- Echinodorus tenellus* (Mart.) Buchenau, Dwarf burhead.

COMMELINACEAE (Spiderwort Family)

- Commelina erecta* L., Day-flower.
Tradescantia bracteata Small, Spiderwort.

CYPERACEAE (Sedge Family)

- Carex decomposita* Muhl., no common name.
Eleocharis radicans (Poiret) Kunth, no common name.
E. tricostrata Torrey, no common name.
Rhynchospora globularis (Chapman) Small, no common name.
Scleria pauciflora Willd., no common name.

IRIDACEAE (Iris Family)

- Sisyrinchium farwellii* Bickn., no common name.
S. hastile Bickn., no common name.

LILIACEAE (Lily Family)

- Disporum maculatum* (Buckley) Britton, Nodding mandarin.
Trillium viride Beck, no common name.

POACEAE (Grass Family)

- Agropyron spicatum* (Pursh) Scribner & J. G. Smith, Bluebunch wheatgrass.
Aristida dichotoma Michaux, no common name.
Digitaria filiformis (L.) Koeler, no common name.
Muhlenbergia cuspidata (Hooker) Rydb., no common name.
Panicum verrucosum Muhl., no common name.
Phleum alpinum L., Mountain timothy.

{POTAMOGETONACEAE (Pondweed Family)}

- {*Potamogeton lateralis* Morong, no common name.}

DICOTYLEDONS

APIACEAE (Parsley Family)

- Polytaenia nuttallii* DC., Prairie-parsley.

ASTERACEAE (Composite Family)

Helianthus microcephalus Torrey & Gray, Small wood-sunflower.

Liatris punctata Hooker, Blazing-star.

Polymnia uvedalia L., Leafcup.

Senecio congestus (R. Br.) DC., Marsh-fleabane.

CARYOPHYLLACEAE (Pink Family)

Silene virginica L., Fire pink.

ERICACEAE (Heath Family)

Vaccinium vitis-idaea L., Mountain-cranberry.

FABACEAE (Pulse Family)

Baptisia leucophaea Nutt., Cream wild indigo.

GENTIANACEAE (Gentian Family)

Gentiana puberulenta Pringle [*G. puberula* Michaux], Downy gentian.

G. saponaria L., Soapwort gentian.

OXALIDACEAE (Wood-sorrel Family)

Oxalis violacea L., Violet wood-sorrel.

PLANTAGINACEAE (Plantain Family)

Plantago cordata Lam., Heart-leaved plantain.

SCROPHULARIACEAE (Figwort Family)

Agalinis gattereri (Small) Small [*Gerardia gattereri* Small], Gerardia.

Aureolaria auriculata (Michaux) Farw., False foxglove.

Buchnera americana L., Blue-hearts.

SPECIAL CONCERN

PTERIDOPHYTES

LYCOPODIACEAE (Club-moss Family)

Lycopodium complanatum L. (sens. str.), Trailing Christmas-green.

Lycopodium selago L., Fir club-moss.

EQUISETACEAE (Horsetail Family)

Equisetum × litorale Kuhl., Horsetail.

POLYPODIACEAE (Fern Family)

Asplenium viride Huds., Green spleenwort.

Camptosorus rhizophyllus (L.) Link, Walking fern.

Cryptogramma stelleri (Gmel.) Prantl, Slender cliff-brake.

Dryopteris expansa (Presl) Fraser-Jenkins & Jermy [*D. assimilis* S. Walker], Shield fern.

Gymnocarpium × heterosporum W. H. Wagner, Oak fern.

Woodsia × abbeae Butters, Woodsia.

MONOCOTYLEDONS

COMMELINACEAE (Spiderwort Family)

Tradescantia virginiana L., Spiderwort.

CYPERACEAE (Sedge Family)

- Carex albolutescens* Schw., no common name.
C. arcta Boott, no common name.
C. concinna R. Br., no common name.
C. davisii Schw. & Torrey, no common name.
C. festucacea Willd., no common name.
C. frankii Kunth, no common name.
C. grvida Bailey, no common name.
C. haydenii Dewey, no common name.
C. hyalinolepis Steudel, no common name.
C. oligocarpa Willd., no common name.
C. pallescens L., no common name.
C. richardsonii R. Br., no common name.
C. squarrosa L., no common name.
C. straminea Willd., no common name.
C. × subimpressa Clokey, no common name.
C. trichocarpa Schk., no common name.
Cyperus flavescens L., Yellow cyperus.
Eleocharis engelmannii Steudel, Spike-rush.
Hemicarpha micrantha (Vahl) Pax, no common name.
Rhynchospora macrostachya Torrey, Beak-rush.
Scirpus torreyi Olney, Torrey's bulrush.

IRIDACEAE (Iris Family)

- Sisyrinchium strictum* Bickn., Blue-eyed-grass.

JUNCACEAE (Rush Family)

- Juncus biflorus* Ell., Rush.

LILIACEAE (Lily Family)

- Smilax herbacea* L. (sens. str.), Carrion-flower.

ORCHIDACEAE (Orchid Family)

- Arethusa bulbosa* L., Arethusa or Dragon's mouth.
Cypripedium arietinum R. Br., Ram's head lady-slipper.
**C. calceolus* var. *parviflorum* (Salisb.) Fern. (sens. str.), Small yellow lady-slipper.
Habenaria flava (L.) Sprengel, Tubercled orchid.
Isotria verticillata (Willd.) Raf., Whorled pogonia.
Listera auriculata Wieg., Auricled twayblade.
Spiranthes casei Catling & Cruise, Ladies' tresses.
S. lucida (H. H. Eaton) Ames, Shining ladies' tresses.
S. magnicamporum Sheviak, Great Plains ladies' tresses.

POACEAE (Grass Family)

- Aristida tuberculosa* Nutt., Beach three-awn grass.
Danthonia intermedia Vasey, Wild oat grass.
Elymus glaucus Buckley, Wild rye.
E. mollis Trin., Wild rye.
Eragrostis capillaris (L.) Nees, Love grass.
E. pilosa (L.) Beauv., Love grass.
Oryzopsis canadensis (Poiret) Torrey, Canada rice-grass.
Panicum microcarpon Ell., Panic grass.
P. philadelphicum Trin., Panic grass.
{*Poa paludigena* Fern. & Wieg., Bog bluegrass.}
Triplasis purpurea (Walter) Chapman, Sand grass.
Trisetum spicatum (L.) Richter, Downy oat-grass.

DICOTYLEDONS

APIACEAE (Parsley Family)

Osmorhiza depauperata Phil. [*O. obtusa* (C. & R.) Fern.], Sweet cicely.

ASTERACEAE (Composite Family)

Aster nemoralis Aiton, Bog Aster.

Boltonia asteroides (L.) L'Her., Boltonia.

Cirsium hillii (Canby) Fern., Hill's thistle.

Eclipta prostrata (L.) L. [*E. alba* (L.) Hassk.], Yerba-de-tajo.

Helianthus hirsutus Raf., Whiskered sunflower.

Rudbeckia sullivantii C. L. Boynton & Beadle, Coneflower or Black-eyed Susan.

Solidago decumbens Greene, Goldenrod.

S. lepida DC., Goldenrod.

S. remota (Greene) Friesner [distinct from *S. tenuifolia* Pursh?], Goldenrod.

BERBERIDACEAE (Barberry Family)

Jeffersonia diphylla (L.) Pers., Twinleaf.

BRASSICACEAE (Mustard Family)

Arabis missouriensis Greene, Rock-cress.

CALLITRICHACEAE (Water-starwort Family)

Callitriche hermaphroditica L., Water-starwort.

C. heterophylla Pursh, Water-starwort.

CAPRIFOLIACEAE (Honeysuckle Family)

Viburnum edule (Michaux) Raf., Squashberry or Mooseberry.

CARYOPHYLLACEAE (Pink Family)

Stellaria longipes Goldie, Chickweed or Starwort.

CISTACEAE (Rockrose Family)

Lechea minor L., Pinweed.

CONVOLVULACEAE (Morning-glory Family)

Cuscuta campestris Yuncker, Dodder.

C. glomerata Choisy, Dodder.

C. indecora Choisy, Dodder.

C. pentagona Engelm., Dodder.

C. polygonorum Engelm., Dodder.

DROSERACEAE (Sundew Family)

Drosera × anglica Hudson, Sundew.

ERICACEAE (Heath Family)

Chimaphila maculata (L.) Pursh, Pipsissewa or Spotted wintergreen.

FABACEAE (Legume Family)

Amorpha canescens Michaux, Leadplant.

Gymnocladus dioica (L.) K. Koch, Kentucky Coffee-tree.

Strophostyles helvula (L.) Ell., Wild bean.

FUMARIACEAE (Fumewort Family)

Adlumia fungosa Greene, Climbing fumitory.

HALORAGACEAE (Water-milfoil Family)

Myriophyllum alterniflorum DC., Water-milfoil.

JUGLANDACEAE (Walnut Family)

Carya laciniata (Michaux) Loud., Big shellbark hickory or King-nut.

LAMIACEAE (Mint Family)

Pycnanthemum verticillatum (Michaux) Pers., Mountain-mint.

Scutellaria parvula var. *leonardii* (Epling) Fern., Skullcap.

LENTIBULARIACEAE (Bladderwort Family)

Pinguicula vulgaris L., Butterwort.

LINACEAE (Flax Family)

Linum sulcatum Riddell, Furrowed flax.

L. virginianum L., Virginia flax.

LYTHRACEAE (Loosestrife Family)

Rotala ramosior (L.) Koehne, Tooth-cup.

MALVACEAE (Mallow Family)

Hibiscus moscheutos L. [*H. palustris* L.], Swamp rose-mallow or Marsh mallow.

MELASTOMATACEAE (Melastoma Family)

Rhexia virginica L., Meadow beauty.

ONAGRACEAE (Evening-primrose Family)

Epilobium palustre L., Willow-herb.

PLANTAGINACEAE (Plantain Family)

Littorella americana Fern., no common name.

POLYGALACEAE (Milkwort Family)

Polygala cruciata L., Milkwort.

POLYGONACEAE (Buckwheat Family)

Rumex maritimus L., Golden dock.

RANUNCULACEAE (Crowfoot Family)

Clematis occidentalis (Hornem.) DC. [*C. verticillaris* DC.], Purple clematis.

ROSACEAE (Rose Family)

Crataegus douglasii Lindley, Hawthorn.

Geum vernum (Raf.) Torrey & Gray, Avens.

Prunus alleghaniensis var. *davisii* Wight, Alleghany plum.

SALICACEAE (Willow Family)

Salix pellita Andersson, Willow.

S. pyrifolia Andersson, Balsam willow.

SAXIFRAGACEAE (SAXIFRAGE FAMILY)

Parnassia palustris var. *neogaea* Fern., Grass-of-Parnassus.

Ribes oxycanthoides L., Wild gooseberry.

SCROPHULARIACEAE (Figwort Family)

Lindernia anagallidea (Michaux) Pennell, False pimpernel.

ULMACEAE (Elm Family)

Celtis tenuifolia Nutt., Dwarf hackberry.

VERBENACEAE (Verbena Family)

Verbena simplex Lehm., Vervain.

VIOLACEAE (Violet Family)

Hybanthus concolor (T. F. Forster) Sprengel, Green violet.

Viola palmata L., Violet.

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PUBLICATION OF INTEREST

WILDFLOWERS OF THE GREAT LAKES REGION. by Roberta L. Simonds and Henrietta H. Tweedie. Chicago Review Press, 213 W. Institute Place, Chicago. 1983. 96 pp.

This is the second edition, retitled, of Wildflowers of Michigan, published in 1978 and favorably reviewed in Mich. Bot. 18:14, 1979. Minor errors have been corrected in this edition. Like the first edition, this is an attractive book with a good selection of representative species grouped by season and habitat. It will be very useful to many people trying to learn our flora.

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NOMENCLATURAL NOTES ON SOME MICHIGAN DICOTS

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Part II of *Michigan Flora*, now in press, will cover the families of dicots from Saururaceae through Cornaceae in the traditional Englerian sequence. Inevitably, some names will be used that are unfamiliar to many people, and perhaps some familiar names will be retained despite published suggestions that they be overturned. Usually, nomenclatural problems have been dealt with by a few words of explanation in the text. However, a few points call for more comment than appropriate in the *Flora*, and a few new combinations are needed in order to use a name for a relatively trivial form in what seems to be appropriate rank and position. (If such a form has never received a name, I feel under no compulsion to provide one, but when one exists, it might as well be used for forms that differ in some especially striking way from the usual state of a species.)

Salix exigua f. *wheeleri* (Rowlee) E. G. Voss, comb. nov.

S. interior var. *wheeleri* Rowlee (Bull. Torrey Bot. Club 27:253–254. 1900).

There is now rather widespread agreement that *Salix interior* Rowlee is not a different species from *S. exigua*, described much earlier (see, for example, Little 1979, p. 261). The above combination is then necessary if one wishes to name the form with \pm densely silky and often much broader leaves that occurs largely on sand dunes around the Great Lakes. Among the syntypes listed by Rowlee was only one collected by Charles F. Wheeler, for whom the taxon was named. The specimen, collected on the shore of Black Lake, Cheboygan County, August 11, 1890, is in the Wiegand Herbarium (CU) of Cornell University, and might logically be selected as lectotype (as I previously suggested, before having seen it: Jour. Sci. Lab. Denison Univ. 44:41. 1956).

Salix clarkei

This name is frequently used for the hybrid *S. candida* \times *S. petiolaris*. Sargent (Gard. Chron. n. s. 10:818. 1878) listed "*S. clarkii*, Bebb." as available from cuttings, but no description was provided nor was any geographic origin stated. The formula "*petiolaris* \times *candida*" was indicated, and two varieties were named, with Latin diagnoses (but these names are invalid under Art. 43 of the Code, since the name of the species was not validly published). *S. clarkei* was discussed by Rowlee and Wiegand

(Bull. Torrey Bot. Club 23:196. 1896), who noted that Bebb's material came from Flint, Michigan, collected by Dr. Daniel Clarke in 1872, but they did not describe it nor did they really accept the binomial for their material from New York (which was described). The binomial was not validly published by Focke (Pflanzen-mischlinge 368. 1881) or Schneider (Jour. Arnold Arb. 3:81. 1921). Although these authors and others have alluded to this hybrid, the name seems never to have been validly published, despite its being included in recent checklists. It is unfortunate that the honor intended for Dr. Clarke, one of the state's pioneer collectors, turns out to be a hollow one. Specimens were distributed by M. S. Bebb as his "Herbarium Salicum" No. 30, of which I have seen sheets in several herbaria, including CU, MICH, and MSC. The MSC sheet has additional data indicating the location of Hascoll's Swamp, the original locality for this and other willows sent by Clarke to Bebb: "N. of N. W. corner of Avondale cemetery and near the Bayou that extends up from Flint river"; as stated in a handwritten description by Bebb on the CU sheet and mentioned by Rowlee and Wiegand (loc. cit.), the locality was obliterated soon after the collections were made.

Comptonia peregrina (L.) Coulter

While I am not following those authors who include *Comptonia* in *Myrica*, attention should be called to the fact that the specific epithet remains the same no matter which generic name is used, although "*Myrica asplenifolia*" (the spelling to be corrected from *asplenifolia*, under Art. 73.8) is a name often seen. *Liquidambar peregrina* and *Myrica asplenifolia* were both published by Linnaeus in 1753. The first author to unite these was Linnaeus himself in 1759 (Syst. Nat. ed. 10, 2:1273). Under Art. 57.2, the first author who unites taxa bearing names of equal priority is to be followed in his choice. Those who do not separate *Comptonia* should call sweet-fern *Myrica peregrina* (L.) Kuntze.

Quercus rubra var. *ambigua* (A. Gray) Fernald

The nomenclature of the red oaks has long been recognized as a messy problem. If one follows Svenson (Rhodora 41:521-524. 1939), as have the U.S. Forest Service (Little 1979), *Gray's Manual* (Fernald 1950), and *Flora Europaea* (1964), in accepting *Quercus rubra* L. as the name for our northern red oak, then at least a well known binomial is preserved.

Within this species, two varieties are often distinguished, although their significance may be debatable (see Overlease in Proc. Pennsylvania Acad. 49:138-140. 1975). The more northern variety is generally called var. *borealis* (Michaux f.) Farw., although the oldest epithet in varietal rank for the taxon seems to be in the combination *Q. coccinea* var. *ambigua* A. Gray (Man. ed. 5, 454. 1867), as was duly noted by Fernald (Rhodora 10:49. 1908). Since the alleged basionym of this combination, *Q. ambigua* Michaux f., is presumably a later homonym of *Q. ambigua* Humb. & Bonpl. (as

indicated by Fernald 1950 and Farwell in Rep. Mich. Acad. 6:206. 1905),¹ Michaux's name is illegitimate and Gray's supposed new combination is instead, as noted under Art. 72, treated as new. Thus it becomes the basionym for the combination *Q. rubra* var. *ambigua* (A. Gray) Fernald. This combination is sometimes (as in the Gray Card Index) attributed to Houba (Les Chênes de l'Amérique Septentrionale en Belgique. 1887). The name does indeed appear on Houba's plate (facing p. 163) but it is very doubtful whether he can be said to have accepted it. On p. 35 he refers to "Rubra Ambigua" but everywhere else he maintains the two as separate species, following F. Michaux, including his plate comparing the fruit and references on pp. 162 and 122, where he accepts Michaux's classification.

Whether one accepts Houba or Fernald as first validly publishing the combination with *Q. rubra*, the varietal epithet *ambigua* (1867) considerably antedates *borealis* (1905) in the same rank. Farwell himself (Am. Midl. Nat. 11:80. 1928) took up *Q. rubra* var. *ambigua*, admitting that his own combination *Q. rubra* var. *borealis* belonged in synonymy. Unfortunately, he has not been widely followed (except for Gray's Manual, ed. 7) nor is the epithet *ambigua* accounted for in any way in the basic checklist on tree nomenclature (Little 1979).

Quercus muehlenbergii f. *alexanderi* (Britton) Trel.

This name is used by Fernald (1950) for the broad-leaved extreme of the yellow or chestnut oak. It is nomenclaturally correct at the rank of form, but sometimes there is confusion about the status of *Q. muehlenbergii* var. *alexandri* (Farw.) Farw. (Am. Midl. Nat. 11:79.1928). For it is sometimes assumed that Farwell was basing his combination on *Q. alexanderi* Britton, which he cited in synonymy. Farwell's basionym, his own *Q. acuminata* var. *alexandri* (Rep. Mich. Acad. 6:206.1905), was, like Britton's epithet, derived from the name of the discoverer, Mr. S. Alexander, of Birmingham, Michigan. However, Farwell explicitly pointed out that his name had been published independently of Britton's (Pap. Mich. Acad. 3:93. 1924). Use of the oldest epithet in the rank of variety would require *Q. muehlenbergii* var. *alexandri* (Farw.) Farw. (Pap. Mich. Acad. 3:93. 1924); the combination *Q. muehlenbergii* var. *alexanderi* (Britton) Camp (Ohio Jour. Sci. 33:421. 1933) is later—regardless of whether one considers it to be a homonym. In the rank of form, however, Fernald (1950) is correct—unless one considers that the two epithets are so similar they are likely to be confused and hence to be treated as homonyms under Art. 64.2. Certainly they would be homonyms if one believed that *alexanderi* had to be "corrected" to *alexandri* to be in accord with Rec. 73C.2. However, Art. 73.10 mandates only corrections of terminations contrary to Rec. 73C.1, not Rec. 73C.2, which deals with

¹The actual date of publication of *Q. ambigua* Michaux f. (Hist. Arb. Forest. Am. Sept. 2:120) was in August 1811. The date for the relevant part of Humboldt and Bonpland (Pl. Aequinoct. 2:51) is less certain, but was between February 1810 and November 1811. The odds are definitely in favor of its antedating Michaux f. (For dates, see Stafleu & Cowan, Taxonomic Literature ed. 2, 2:368. 1979.)

epithets derived from personal names "already in Greek or Latin, or possessing a well-established latinized form," such as Alexander.

If the two epithets should be considered the same, the picture becomes even more complicated. Farwell's 1905 name (*Q. acuminata* var. *alexandri*) is the first at an infraspecific rank, and its transfer by Farwell to *Q. muehlenbergii* dates from March 15, 1924 (see McVaugh in Pap. Mich. Acad. 38:42. 1953). Trelease's *Q. muehlenbergii* f. *alexanderi* (Mem. Natl. Acad. Sci. 20:111) surely dates from *later* in 1924. (The University of Michigan library copy was, e.g., received from the Government Printing Office on January 2, 1925.) Hence, Trelease's name at rank of form would, under Art. 64.3, be a homonym as it is based on a different type (Britton's), and a new combination at rank of form, based on Farwell's name, would be required.

Arceuthobium pusillum Peck

This name is attributed in Kartesz and Kartesz (1980) to M. E. Peck, the Oregon botanist. The author was actually C. H. Peck, the distinguished New York botanist. *A. pusillum* was described by Charles Peck when Morton Peck was only one year old, and too small to describe even a dwarf mistletoe.

Nuphar variegata f. *lutescens* (Farw.) E. G. Voss, comb. nov.

Nymphozanthus variegatus var. *lutescens* Farwell (Am. Midl. Nat. 8:270. 1923).

The type (Farwell 6663, BLH) has leaves with flat, even winged, petiole and shape of blade as in *N. variegata*. The flowers, however, evidently lacked the large deep red area normally found at the base of the sepals, for as Farwell noted on his label, "pure yellow flowers" was the fresh appearance.

Anemone quinquefolia var. *bifolia* Farwell

This name was published by Farwell in 1923 (Pap. Mich. Acad. 1:94) for a plant with only two involucre leaves rather than the customary three. Twelve years later, Fernald (Rhodora 37:260. 1935) described *A. quinquefolia* var. *interior* for the spreading-villous plants which occur in the Great Lakes region and elsewhere in the western portion of the range of the species. He admitted awareness of Farwell's name, but dismissed it as an aberration and declared that to take it up would "be quite misleading and unjustified"—although later in the same paper (p. 328) he defended the priority principle in spite of the motive of botanists in the past "to reject an inappropriate name in favor of an appropriate one"!

Filed with the type (Farwell 5431, BLH), which indeed has spreading pubescence, is a carbon copy of a letter from Farwell to Fernald, dated November 9, 1935, decrying several of Fernald's actions and defending the International Rules, including this passage, which is so well expressed that I need add nothing further:

Also in a more recent article you have set aside my *Anemone quinquefolia* L. var. *bifolia* for a varietal name of your own, viz.—*interior*. There is nothing in the I. R. that will substantiate such action; on the contrary, it is a flagrant violation of the I.R. My type specimen will be found to be identical with your own except as to the number of involucral leaves and since you consider them synonymous my varietal name, under the I. R., must prevail. Your argument that my plant is an aberration and not a truly geographical var. will not hold water as aside from the character I used the characters of it are identical with those of your own, therefore it is a good geographical variety. The fact that I used what you call an aberrant character, instead of the characters satisfactory to yourself is entirely beside the matter.

Fernald was obviously unmoved by this outburst, and continued to use the incorrect name in *Gray's Manual* (1950).

Brassica alba (L.) Rabenhorst

Brassica hirta Moench is often used when *Sinapis alba* L. is included in the genus *Brassica*. This is done, for example, in *Gray's Manual* (Fernald 1950) and even in the "Punt Report" (Prel. Rep. Stabil. Names Pl. Econ. Imp., Reg. Veg. 36. 1964). The reason put forth for not retaining the Linnaean epithet upon transfer to *Brassica* is that there already was a *Brassica alba* Gilib. (see L. C. Wheeler in *Rhodora* 40:306. 1938). However, Gilibert's name was not validly published (either originally or in reprinted form) as it was not in a work in which the Linnaean system of binary nomenclature was consistently employed (Art. 23.6(c), including examples) and hence not even the binomials which happen to be in such works can be used; they are considered not validly published, under Art. 32.1(b). Consequently, later use of such binomials does not create homonyms, for invalid names have no standing whatsoever under the Code. The correct use of *B. alba* (L.) Rabenhorst was pointed out by Jones and Fuller (Vasc. Pl. Illinois 228. 1955), but apparently it is necessary to state the case again.

Polygala polygama* f. *ramulosa (Farw.) E. G. Voss, comb. nov.

P. polygama var. *ramulosa* Farwell (Am. Midl. Nat. 11:62–63. 1928).

The type (Farwell 8068, BLH) has numerous leafy branches with racemes or spikes of apparently cleistogamous flowers (ranging from buds to immature fruits, all lacking developed perianth)—in addition to normal subterranean racemes of cleistogamous flowers. Such leafy- or bushy-looking plants occasionally occur in this species, and if they deserve a name it should be no more than at the rank of form.

Polygala sanguinea L.

This name and *P. viridescens* were both published by Linnaeus in 1753. Gillett (Milkworts of Canada, Canada Dep. Agr. Monogr. 5:17. 1968) noted that most authors have considered the names synonymous and stated that the first authors to unite the two were Britton and Brown in 1897, who chose *P. viridescens*, which would then be the name to use, under Art. 57.2.

However, the two had been merged long before, under the name *P. sanguinea*, by Torrey and Gray (Fl. N. Am. 1:126. 1838).

Nemopanthus mucronatus (L.) Loesener

Loesener (in Koehne, Deut. Dendrol. 372. 1893) fully cited the Linnaean basionym, *Vaccinium mucronatum* (Sp. Pl. 350. 1753), but not the place where the combination was made by Trelease, to whom he attributed it. However, Loesener later (Monogr. Aquifol., Nova Acta Acad. Caes. Leop. Carol. 78:501. 1901) recognized that Trelease's combination—which authors continue to use to this day—was merely “in obs.” Indeed, Trelease (Trans. Acad. Sci. St. Louis 5:349. 1892) accepted *N. canadensis* as the name for this plant, noting that “the attempted change in principles of nomenclature would cause it to bear the name *N. mucronata* (L.)”. Trelease's widely used combination cannot be accepted under Art. 34.1, as it was not accepted by him—a suggestion made (although for some reason not adopted) by Little (1979, p. 177, where only the later work by Loesener is cited).

It should also be noted that under Rec. 75A.2(c), the generic name (like all names ending in *-anthus*) should be treated as masculine, although technically it ought to be neuter.

Acer saccharum* var. *viride (Schmidt) E. G. Voss, comb. nov.

A. saccharinum var. *viride* Franz Schmidt (Anleit. Erzieh. Vermehr. Ahornart. tab. 9. 1812; fide Fosberg 1954 & Little 1979).

While I am exceedingly reluctant to burden the literature with any new name in the genus *Acer*, the above combination is apparently necessary if one wishes to treat black maple as a variety of sugar maple and to call the latter *A. saccharum* Marshall. The case for retaining the familiar name *A. saccharum* has been repeatedly made (e.g., Sprague in Kew Bull. Misc. Inform. 1929:81–82. 1929; Gleason in Phytologia 2:206–207. 1947; Shaw in Rhodora 79:123–127. 1977): I find it convincing. There is no clear evidence that Marshall's epithet *saccharum* was a typographical error for *saccharinum*, and we have to accept what he did, not what we think he might have done, in using the name *Acer saccharum* for sugar maple. Evidently he called silver maple *A. glaucum*.

As pointed out by Fosberg (1954), while accepting *A. saccharophorum* K. Koch for sugar maple, the oldest epithet in varietal rank for black maple is the basionym cited above, published in a work of which he was unable to locate a copy in this country. This antedates any applicable autonym at the rank of variety, so even under the new rules adopted at Sydney the above combination is required. Shaw (loc. cit.) cited *A. saccharum* var. *nigrum* (Michaux f.) Britton (1889) as the correct name at varietal rank if one did not treat *A. nigrum* as a separate species.

A NOTE ON AUTONYMS

Automatically created names for taxa that include the type of the name at the next higher rank and that repeat the epithet of that name—such as *Quercus rubra* var. *rubra*—were born at the VII International Botanical Congress (Stockholm 1950). They were christened as “autonyms” at the XI Congress (Seattle 1969) but with a distinct warning that they were “not to be taken into consideration for purposes of priority.” However, at the XIII Congress (Sydney 1981), autonyms acquired new status and are now not only to be considered validly published (even when never effectively published) but also to take priority over the names of the same date and rank that automatically established them (Art. 57.3). They are thus a definite exception to the long-standing rule of the “first reviser” which otherwise permits selection from among names of the same date when the taxa to which they apply are combined (Art. 57.2).

In general, the new autonym rule is relevant only when one merges (into another taxon) a taxon in which subordinate taxa have been named at the rank to be assigned under that other taxon. If a name is needed at a rank for which an autonym exists, in other words, the epithet of the autonym must now be used in a new combination rather than the epithet(s) of the same rank and date that automatically created the autonym (unless the autonym *and* the name(s) that created it are *both* to be used in the new position). There has been some unhappiness and confusion among botanists over this change for, as a Rule, it is retroactive. New combinations were illegitimate under previous editions of the Code if, under the circumstances described above, they did not use an epithet other than from an autonym. Under the Sydney Code (“this Code” of Art. 6.4), they have become legitimate if they used the epithet of an autonym. All this should become clearer from the following examples, which I was surprised to realize are apparently the only ones encountered among the nearly 1000 species covered in Part II of *Michigan Flora*; all of them involve names that my taxonomic dispositions would not employ.

Nuphar advena (Aiton) Aiton f.

I choose to recognize this pond-lily as a distinct species, and hence do not publish a combination under *N. lutea* (L.) Sibth. & Sm., lest it be considered invalid under Art. 34.1(a) [not accepted by the author]. However, those who follow the alternative position of E. O. Beal have, until 1981, correctly used the name *N. lutea* ssp. *macrophylla* (Small) E. O. Beal if they wished to treat this taxon as a subspecies of *N. lutea*, for *macrophylla* (1912) was, prior to 1981, considered the oldest available epithet at that rank. Now, the autonym dating from 1912 [*Nymphozanthus advena* ssp. *advena*] has to be treated as having priority and the combination with *N. lutea* has yet to be made. [For full synonymy, see Beal in Jour. Elisha Mitchell Sci. Soc. 72:332–333. 1956.]

Amelanchier laevis Wieg.

Again, I prefer to recognize this species as distinct, but it has sometimes been considered to be merely a variety of *A. arborea* (Michaux f.) Fern. Prior to the current Code, the correct name was *A. arborea* var. *cordifolia* (Ashe) Boivin (Nat. Canad. 93:432. 1966), at least if one chose not to recognize both var. *cordifolia* and var. *laevis* but to treat both as a single variety of *A. arborea*. Now, we would use the previously illegitimate *A. arborea* var. *laevis* (Wieg.) Ahles (Jour. Elisha Mitchell Sci. Soc. 80:172. 1964).

Baptisia leucophaea Nutt.

In merging this species with the southeastern *B. bracteata* Ell., Isely (Brittonia 30:470. 1978) noted that "Larisey's obscure name for the less pubescent forms of *B. leucophaea* must be taken up at varietal rank." The combination *B. bracteata* var. *glabrescens* (Larisey) Isely was indeed correct in 1978, but now a combination based on the autonym *B. leucophaea* var. *leucophaea* would be in order (see Art. 57 Note 1).

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NOTICE: MICHIGAN FLORA II

Part II of *Michigan Flora*, by E. G. Voss, will cover the first half of the dicots, families Saururaceae through Cornaceae (exactly the same coverage as Vol. 2 of Gleason's Illustrated Flora). The work is now in press and is expected to be available late in the summer. It includes full keys, 971 distribution maps, 97 pages of figures, 9 color plates, and follows closely the format of Part I (Gymnosperms and Monocots), published in 1972.

Persons wanting to receive a copy as soon as it is published may order Bulletin 59 from Cranbrook Institute of Science, Attn. Publications, Box 801, Bloomfield Hills, Michigan 48013. The price is \$12.50, plus \$1.25 postage and handling. Add \$.50 sales tax for orders to be sent to a Michigan address.

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**EURASIAN INTRODUCTIONS TO THE
MICHIGAN FLORA. III.**

Richard K. Rabeler & Cheryl A. Crowder¹

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**ADDITIONAL NOTES ON SPECIES REPORTED IN
PARTS I AND II.**

Medicago sativa L. subsp. \times *varia* (T. Martyn) Arcang.

The initial discussion of this taxon (Rabeler & Gereau, 1984) noted that collections had been seen from eight counties. Information provided by Dr. Edward Voss on specimens at AUB, BLH, ND, and WUD along with recent collections made or seen by Rabeler have added records for nine additional counties: Bay, Berrien, Cass, Clinton, Eaton, Kent, Leelanau, Livingston, and Oakland.

Ranunculus ficaria L.

Two colonies of this species were discovered by a local Michigan Botanical Club member shortly after the appearance of the initial report in Part II (Gereau & Rabeler, 1984), adding a second county to the known distribution in Michigan.

MICHIGAN. EATON CO.: At base of dead *Fraxinus*, 35 ft N of N bank of Grand River, 600 ft W of trail jct., *R. Blouch s. n.*, 22 May 1984 (MSC); at base of *Populus deltoides* adjacent to N bank of Grand River, 240 ft E of trail jct., *R. Blouch s. n.*, 31 May 1984 (MSC, PAC, WMU); both collections made 0.25 mi S of Delta River Dr., 0.25 mi W of Waverly Rd., T4N, R3W, S1, NW $\frac{1}{4}$ of SE $\frac{1}{4}$.

Apera spica-venti (L.) Beauv.

The recent report of this species as a common plant in cultivated cereal-grain fields in two additional counties indicates that, as suggested in Part II (Gereau & Rabeler, 1984), the agricultural community should be concerned with the spread of this grass.

MICHIGAN. SAGINAW CO.: Scattered plants in oat field adjacent to Bronner's Christmas Store, E. Curtis Rd., Frankenmuth, T11N, R6E, S27, *S. N. Stephenson s. n.*, 1 July 1984 (MSC); HURON CO.: Common in wheat field, Willard Jurgess farm, N side of M-142, 0.1 mi E of Verona, T16N, R14E, S19, NW $\frac{1}{4}$, *Colby s. n.*, 24 July 1984 (BLH, DAO, MSC, NY, TAES, WMU).

Solheim and Judziewicz (1984) reported the appearance of *Apera interrupta* (L.) Beauv. in Wisconsin in 1981. They suggested that this species may be spreading into eastern North America, quite possibly as a

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contaminant in turf seed mixtures from the Pacific Northwest where it is an established weed.

NEW SPECIES

Astragalus cicer L.

The Chick-pea milk-vetch is widely distributed in a variety of habitats over much of continental Europe (Barneby, 1964). Although introduced over 50 years ago into both the United States and Canada as a cover or forage crop (for insight into the agricultural uses, see Johnston et al., 1975; Stroh et al., 1972), only a few reports of naturalized *Astragalus cicer* exist. Isely (1984) aptly summarized the situation when he stated that the "scant herbarium record of *Astragalus cicer* evidently poorly portrays its occurrence in the United States." Barneby (1964) noted collections from Washington (Whatcom Co.) and Nevada (Elko Co.). Welsh (1978) mentioned the occurrence of *A. cicer* in Utah while Weber, Johnston, and Wilken (1979) listed two 1978 collections from Colorado. Isely (1984) referred to a Wyoming collection of *A. cicer* and mentions personally having seen "it in urban areas in several western states." Canadian reports are limited to an occurrence as a weed in a clover field at Brandon, Manitoba in 1958 (Scoggan, 1978), a field weed at Stavely, Alberta (Boivin, 1967), a roadside collection at Sainte-Foy, Quebec [J.-P. Bernard B375 in 1974, DAO (ex QFA); see Cayouette et al. (1983)], and a mixed collection from the grounds of the Central Experimental Farm at Ottawa, Ontario F. J. Beales in 1982 (DAO); flowers of *Coronilla*, fruits of *Astragalus cicer*. The only material from the eastern United States that we could locate were two collections made near Syracuse, New York (F. S. Raleigh in 1982, BH) from a road bank that had been intentionally reseeded, and a collection from the USDA Nursery in Beltsville, Maryland (collector unknown, in 1956, US).

The specimens cited below represent reports from the only locality for the species in Michigan:

MICHIGAN. INGHAM CO.: Trailing plants abundant among young planted *Pinus*, adjacent to S side of Grand Trunk Western Railway right-of-way, 25 m W of Farm Lane, NW of Farm Lane—Service Road intersection, Michigan State University campus, T4N, R1W, S19, NW ¼, Parmelee 3388, 8 Nov 1974 (MSC); Parmelee 3389, 8 Nov 1974 (MICH, MSC, VT); Parmelee 3392, 10 July 1975 (AUB, DAV, MSC, UC, UMO); Parmelee 3393, 14 July 1975 (CAN, GA, ILL, MO, MSC, MTMG, UTC, WUD); Rabeler and Crowder 752, 9 July 1984 (BH, BLH, COLO, DAO, GH, ISC, MICH, MIN, MO, MSC, NA, NLU, NY, OSH, RSA, SMU, TEX).

It is not known when these plants first appeared, although it is apparent by the large area covered and robust stature that *A. cicer* has become firmly established at this site over the past ten years. Ramets from this population were transplanted in the mid-1970's to the W. J. Beal Botanical Garden, approximately one mile northwest of this site, where the species is thriving in cultivation (G. Parmelee, pers. comm.).

ACKNOWLEDGMENTS

We thank Dr. George Parmelee for his collections of *Astragalus cicer*, Rupert Barneby for his observations on *Astragalus cicer* in North America, the curators of A, BH, DAO, and MICH for providing information on specimens of *Astragalus cicer* (or the lack thereof) in their respective collections, and the following people for their help in inspecting collections in other herbaria; Dr. Thomas R. Dudley (NA), Roy E. Gereau (MO), Dr. Neil Harriman (US), Dr. Barney Lipscomb (SMU), and Nick Stoyanoff (MOR).

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On the cover: *Epipactis helleborine*, an introduced orchid,
photographed in Ontario, Canada by Joyce Reddoch on
6 August 1971.

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THE

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245 VIOLA EPIPSILA NEW TO MICHIGAN AND THE EASTERN UNITED STATES

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The circumboreal *Palustres* complex in the genus *Viola* is readily separable from other violets by the combination of purple corollas, broadly ovate to reniform, crenulate, undivided leaves, non-adnate stipules, filiform stolons, and creeping stoloniform rhizomes. Both diploids with $2n = 24$ chromosomes and tetraploids with $2n = 48$ chromosomes are known in the complex. Current taxonomic treatments give the epithets *Viola epipsila* Ledeb and *V. palustris* L., to the diploid and tetraploid levels respectively (Sorsa 1968). Within each level several morphologically distinguishable forms have been accorded varietal or subspecific status. The complex appears phylogenetically closest to and has recently been classified with the stoloniferous white-flowered violets of the subsection *Stolonosae*, particularly close to *V. macloskeyi* Lloyd, including *V. pallens* (Banks) Brainerd (Clausen 1964; Sorsa 1968).

In North America the *Palustres* group is represented by two species and a third entity. Our diploid material is referable to *V. epipsila* ssp. *repens* (Turcz.) Becker. The diploid has been documented from Alaska to Manitoba and southward through the Rocky Mountains to California, Utah, and South Dakota. Prior to this report its easternmost extent was represented by a few local populations on the North shore of Lake Superior in Ontario, some 600 miles disjunct from its mass range in western North America.

Two geographically isolated tetraploid plants with distinct morphologies and origins are known (Sorsa 1968). The eastern form has been formally described, and is the plant to which the name *V. palustris* was originally applied by Linnaeus. This "eastern *palustris*" ranges from Eurasia west to Quebec and the White Mountains of New England in the United States. The unnamed tetraploid, referred to here as "western *palustris*", is included completely within the range of diploid *V. epipsila* discussed earlier. The two forms of *V. palustris* have been lumped together by taxonomists in spite of the many differences separating them. Their nearest documented occurrences are over 1000 miles distant.

All three *Palustres* violets grow in damp cool situations such as alpine meadows, open bogs, and along waterways under alders. All three reportedly hybridize with *V. macloskeyi* s. l. wherever they co-occur with that species.

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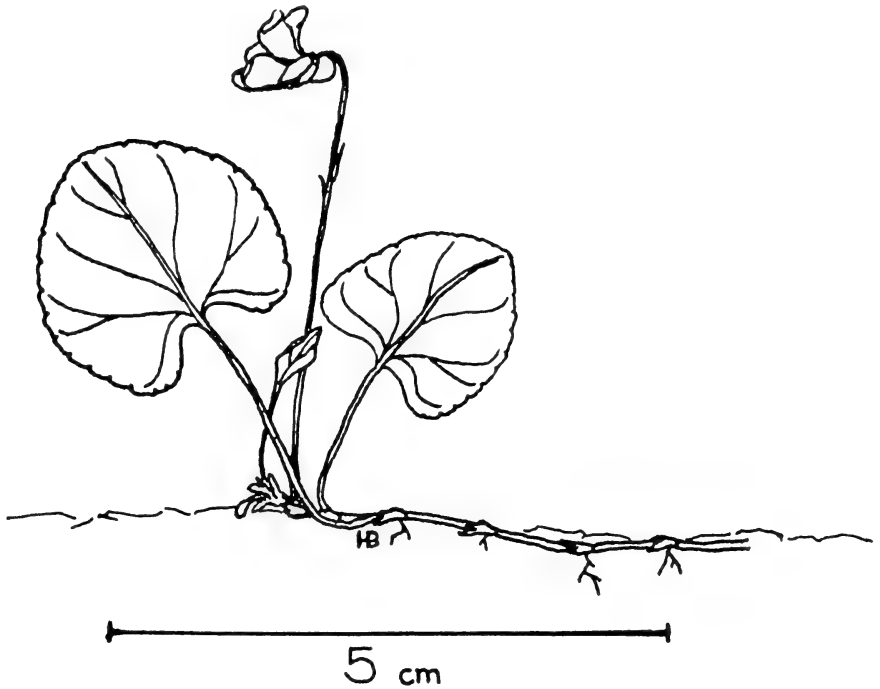


Fig. 1. *Viola epipsila* ssp. *repens* in flower.

Indeed, Sorsa (1968) has presented convincing evidence to suggest that "western *palustris*" was produced through such hybridization.

While examining material from BLH (Cranbrook Institute of Science) and CAN (National Herbarium, Ottawa, Canada) I discovered several sheets which clarify the range of *V. epipsila* in northcentral North America. One sheet from BLH consisted of four specimens from Manitou Island off the Keweenaw County coast of Michigan. The specimens had been misidentified as "*Viola incognita* Brainerd" by the collector and by N. H. Russell. Russell's failure to recognize the specimens as *Palustres* violets is inexplicable. Beyond the obvious features identifying them as such, the plants possessed the noticeably long spurs, bracteoles attached above the middle of the peduncles, and 2-3 obtusely pointed leaves that are the hallmark of *V. epipsila* ssp. *repens* (Fig. 1). The sheet at Cranbrook is the basis for the first verified report of *V. epipsila* ssp. *repens* from Michigan and the eastern United States. Examinations of violet specimens from all major and most minor Michigan herbaria have failed to yield additional specimens of this species in the state.

Specimens were first seen from DAO (Department of Agriculture, Ottawa) that were the basis of reports from the Thunder Bay area in Ontario. However, several sheets from CAN greatly increased the range of *V. epipsila*

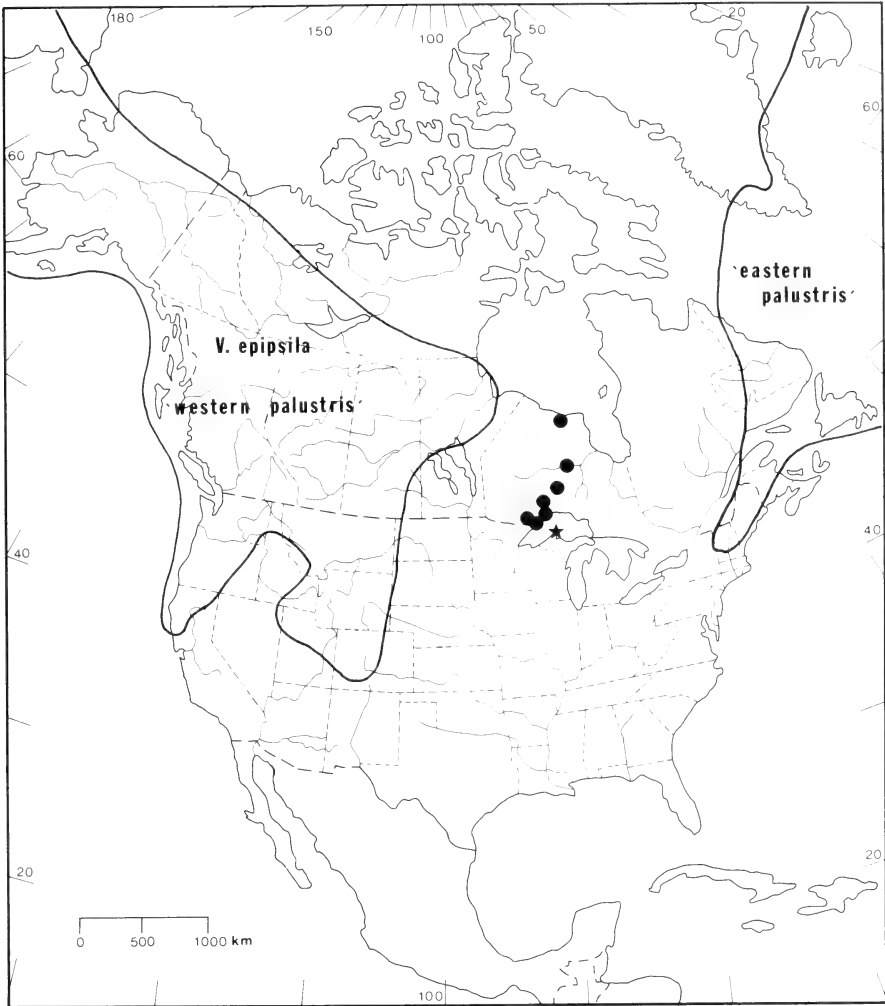


Fig. 2. Distribution of *Palustres* violets in North America (modified from Hulten, 1958). Star = new Michigan station for *V. epipsila*. Dots = Ontario stations for *V. epipsila* discussed in text.

in the province. The widely disparate locations strongly suggest that the species occurs throughout central Canada. But because of the absence of roads, and of difficult environmental conditions during its blooming time (cold temperatures, black flies, etc.), the violet may have escaped attention of botanists.

Earlier published reports of *V. epipsila* in Ontario indicated its occurrence was confined to a handful of local populations in the Thunder Bay area, and the species was therefore included in a list of species currently under

consideration for "threatened" status. While several additional and widely scattered stations have recently been added to its range in the province, documented reports of it still number less than a dozen, and the violet remains under review.

The Manitou Island station is as yet the only Michigan location for *V. epipsila*, but suitable habitats for it can be found elsewhere in northern Michigan, especially on Isle Royale and the eastern tip of mainland Keweenaw County. Perhaps some lucky naturalist on Isle Royale will one day wander into a lakeside alder thicket out of curiosity and look more closely at that small lilac-flowered violet.

ACKNOWLEDGMENTS

I am grateful to the curators of BIH, CAN, DAO for the loan of *Viola epipsila* specimens, and to A. A. Reznicek and E. G. Voss at MICH for helpful discussions and encouragement.

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**VEGETATION AND CHEMICAL ANALYSIS OF A SALT
MARSH IN CLINTON COUNTY, MICHIGAN**

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Salt marshes occurring inland from the Atlantic and Gulf coasts are a unique and extremely rare habitat in eastern North America. Recognizing this, the Michigan Natural Features Inventory (MNFI) studied a salt marsh located near the Maple River (T8N, R4W, Sec. 15) in Clinton County, Michigan. MNFI wanted to establish ecological baseline data for monitoring changes in the marsh and for comparison with other inland salt marshes. The main objective of the study was to correlate variation in soil salt concentrations with vegetation pattern in the marsh, thereby establishing that the highest soil salt concentration corresponds with dominant species different than the dominants of lower salt areas, and that salt-tolerant plants (halophytes) are restricted to soil of highest salt concentration.

Inland salt marsh depends on natural springs or seeps. Water laden with sodium chloride saturates the ground and creates intolerable conditions for most vascular plants. But halophytes, which migrated inland from the extensive saline habitats of the Atlantic coast, can grow naturally at such places.

Inland salt marsh is a very rare community of local occurrence in eastern North America, the result of original rarity and post-settlement exploitation. Salt marsh may have been known to settlers as deer (buffalo, salt, etc.) lick, salt spring, and natural brine, but many salt springs and seeps had no salt marsh vegetation or halophytes (Houghton 1837, Catling & McKay 1981, Alison Cusick pers. comm.). Because of high demand for salt, beginning with settlement (Winchell 1861, Cook 1914, Allen 1918, Gere 1974), salt sources were sought out, exploited, and consequently, altered permanently. Urban development since 1945 has destroyed additional springs and marshes. State Natural Heritage Programs in New York, Missouri, Illinois, Ohio, Pennsylvania, and Virginia provided information on the present distribution of salt marshes in the East. In New York two natural salt marshes and other more disturbed sites exist near Montezuma. Although nearly forty natural salt springs and marshes are documented by MNFI, only two salt marshes of good quality were found in Michigan despite intensive inventory efforts. Two salty habitats created by humans through brine drilling and road salting were found near Detroit (Brown 1917, Farwell 1916, Reznicek 1980), but halophytes growing there were introduced (Catling & McKay 1981). A few salt springs and associated salt marsh vegetation have been found in Howard

Co., Missouri. Two salt marshes from the Illinois River Valley west of Ottawa, Illinois, are reported. But in Ohio, where native halophytes possibly did occur (Catling & McKay 1981), no salt marshes are known, although salt licks and seeps still can be seen in southeast Ohio. In Pennsylvania, despite natural salt springs, no halophytes have been collected (Catling & McKay 1981) and no saline wetlands found. Following the exploitation of salt springs in Saltville, Virginia, several halophytes probably were introduced, perhaps by birds (Ogle 1981).

SITE DESCRIPTION

The Maple River Salt Marsh occupies seven acres in the floodplain of the Maple River and is separated from the river by a strip of slightly elevated woods of young *Acer saccharinum*, *Fraxinus americana*, and some *Ulmus americana* (Figure 1). The strip is narrowest at the upstream, or east, end of the marsh, and river water at flood stage flows directly into the marsh. Local topography suggests that the marsh occupies a former river channel. As the terrain rises gradually to the north, *Quercus alba* becomes important in the second-growth woods.

The soil of the marsh is mapped Ceresco fine sandy loam (Pregitzer 1978), an alluvial soil of level, poorly drained ground in floodplains. This soil series typically forms as natural levees or as flats raised slightly above the river. The woods along the river grow on Sloan loam, another poorly drained alluvial soil of floodplains. The higher ground north of the marsh is Spinks cobbly sandy loam, a very droughty soil of low natural fertility.

In the east half of the marsh the vegetation grows profusely to a height of about 1.5 m by the end of the summer. *Carex lacustris* dominates in the early summer, but is equalled by *Aster simplex* in the fall when other composites (*Eupatorium maculatum*, *E. perfoliatum*) attain their greatest size. About 100 m² of ground is bare mud or thinly vegetated, and *Scirpus olneyi* and *Eleocharis parvula*, Michigan's two native halophytes (Catling & McKay 1981, Reznicek 1980), are restricted to this area, termed the halozone (Figure 2). It was assumed that salt water for the marsh issued from the halozone's center.

This marsh is the only Michigan site where the threatened *Scirpus olneyi* and *Eleocharis parvula* grow together. The bulrush was collected in 1960 by E. G. Voss et al. and the spike rush in 1980 by S. R. Crispin, MNFI botanist. Both plants were collected in the late 1800's by C. F. Wheeler at a nearby—but unlocatable—salt marsh two miles northwest of Hubbardston. *Scirpus olneyi* also was found in salt marshes by Houghton (in 1837) on the Maple River in Gratiot County (T9N, R2W, Sec. 29), by E. J. Cole and W. E. Mulliken (in 1899) on the Grand River in Kent County (T6N, R12W, Sec. 3), and near the Maple River Salt Marsh by MNFI field worker L. A. Scaddelee (in 1983).

Prior to settlement by Europeans, the locations of salt springs were known to the aboriginal population, probably because animals had found and used them first. Of the Maple River marsh, Houghton (1837) wrote it had

“long been known to the natives as favorite haunts to deer and other wild animals” (p. 110). Most of the saline marshes and springs Houghton mentioned in his notes were well used by animals. At four of the twenty salt springs he visited in the summer of 1837, companies of men were extracting salt, and earlier attempts had been made at four others, although the country had been opened for settlement just that spring.

On 22 July 1837, Houghton (1838) found the oak openings on the terrace north of the east (which he called the “upper”) marsh laid off into the

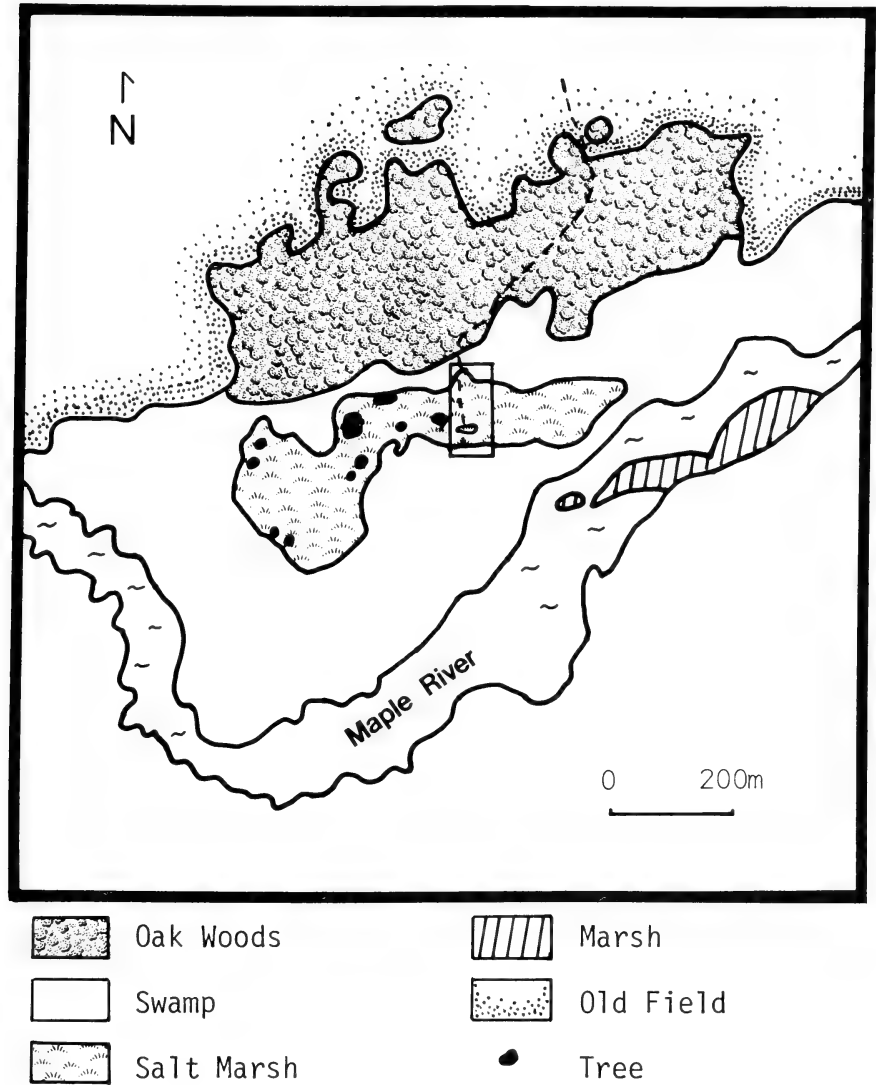


Fig. 1. Vegetation of the salt marsh and surrounding area drawn from an aerial photograph.

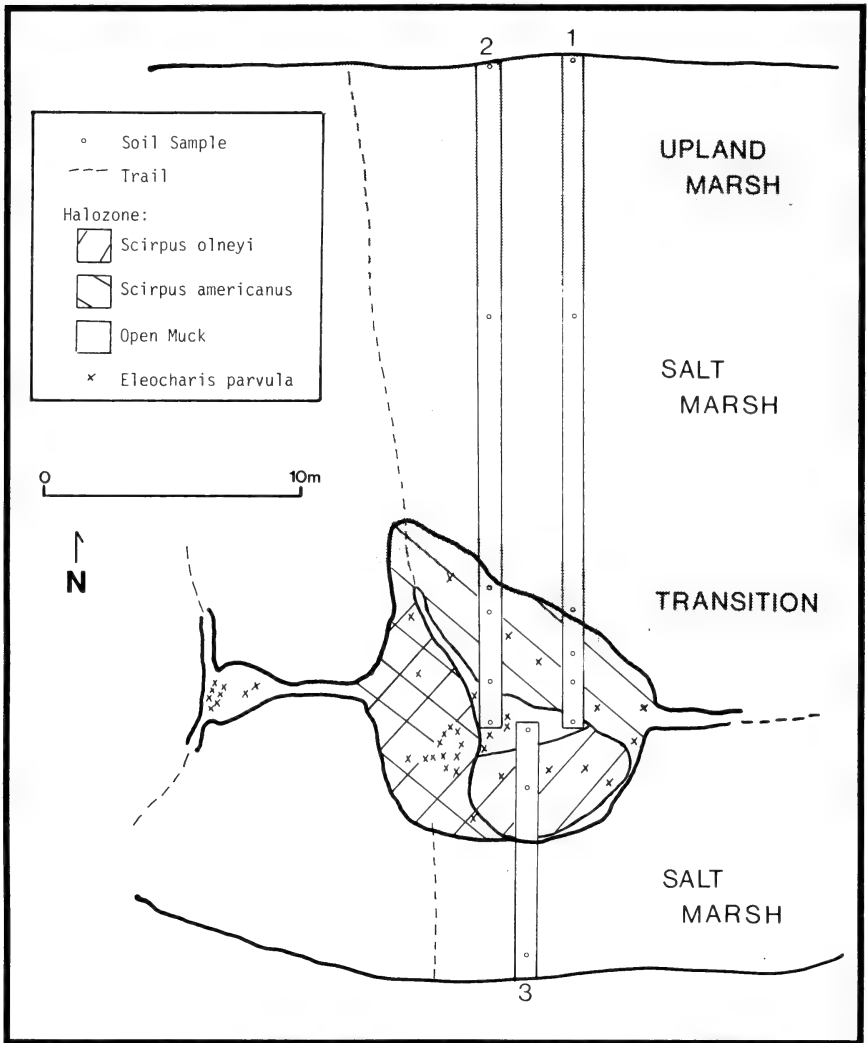


Fig. 2. Location of halozone and transects within the salt marsh.

town of "Clinton Saltworks". A wooden crib had been sunk around the spring and excavated to exclude fresh water, without success. In the following year a shaft was drilled 40 feet, producing brine with over twice as much NaCl as before. The fledgling town and any evidence of both crib and shaft are completely obliterated.

METHODS

Reconnaissance of the marsh took place on 21 May 1981. A second visit was made on 24 September 1982 when two transects (Figure 2), each 25 m long, were run from the north

perimeter of the open marsh to the center of the halozone. Changes in vegetation from the halozone center to the marsh perimeter were detected by recording in each meter of transect the length of aerial portions of each species intersecting the transect. The transects were examined for indications of zonation; for instance, a zonal transition occurs where important species markedly decrease or increase in coverage. Within each zone thus determined, frequency was tallied in 1 m segments of the transect. For each species, percent cover and percent frequency were calculated by zone. Importance values were calculated by summing relative percent cover and relative frequency values. Importance values for species in the entire marsh (except the halozone) were determined in the same way. The halozone and rest of the marsh were searched separately for species not encountered on the transects, and the abundance of each species was visually estimated using a simple scale of cover values.

Samples of soil for chemical analysis were taken from the soil surface (free of standing water on 24 September) and placed in standard glass sampling bottles. Samples were obtained at six spots along Transect 2 (Figure 2). An additional sample was taken at the end of Transect 1 in the center of the halozone along that line. On 2 June 1983, a set of soil samples was collected along Transects 1 and 2 in the flooded marsh, and three samples were taken along a new transect running south from the halozone center. Soil samples were analyzed for sodium (Na^+), chloride (Cl^-), potassium (K^+), calcium (Ca^{++}), magnesium (Mg^{++}) ions, and pH using standard methodology (Environmental Protection Agency 1979). Concentrations of ions are given as g/kg of dried soil.

CHEMICAL AND VEGETATIONAL GRADIENTS

In seven soil samples along Transects 1 and 2, high values for Na^+ , Cl^- , and K^+ were obtained in the halozone or at the halozone edge (Table 1). Concentrations of Na^+ , Cl^- , and K^+ , with one exception, are lowest in the outermost zone (16–25 m from the center), referred to as upland marsh to emphasize its difference from the rest of the marsh. The 1982 sample in Transect 2 had slightly higher K^+ concentration than expected, which was nevertheless below the level of K^+ in the halozone. Ca^{++} , Mg^{++} , and pH have high values, with two exceptions, in the upland marsh. The 1983 sample in Transect 1 showed higher Ca^{++} concentration and pH at 15 m from the halozone center, but the upland marsh values for Ca^{++} and pH were still higher than the remaining samples. In summary, Na^+ , Cl^- , and K^+ tend to increase from the upland marsh to the halozone edge or halozone while Ca^{++} , Mg^{++} , and pH tend to decrease. Along this salinity gradient, concentration of Na^+ and Cl^- changes to a greater degree than Ca^{++} and Mg^{++} and to an even greater degree than K^+ . In all but two instances, the concentration of Na^+ , Cl^- , and K^+ decrease from the halozone edge or halozone toward the halozone center. Along Transect 3 the concentration of Na^+ , Cl^- , and K^+ also was highest in the halozone; Ca^{++} was high along the transect and Mg^{++} very low—much lower than along Transect 1 and 2.

Transect analysis showed concentric zones of vegetation north of the halozone center (Figure 2). The greatest vegetative cover (Table 2) was in the upland marsh where *Aster simplex*, *Carex lacustris*, and *Calamagrostis canadensis* dominate. Transects were not combined in the next zone (halozone marsh) because cover values of important species varied more than in other zones. In both transects total cover was lower than in the upland marsh, mostly due to the great decrease in *Calamagrostis*. *Typha latifolia*, *Scirpus americanus*, and *Eupatorium perfoliatum*, important species of the halozone,

TABLE 1. Mineral concentrations of soil samples taken in the salt marsh along three transects, Fall 1982 and Spring 1983.

	Distance from Halozone Center (m)	Vegetative Zone	Concentration (g/kg)												pH
			Na ⁺		Cl ⁻		K ⁺		Ca ⁺⁺		Mg ⁺⁺				
			82	83	82	83	82	83	82	83	82	83			
Transect 1	25	Upland Marsh		1.1		1.3		1.7		9.2		5.7		7.2	
	15	Halozone Marsh		1.9		1.6		1.9		10.0		5.6		7.8	
	4.5	Transition		1.5		2.7		1.9		8.9		4.7		6.8	
	2.5	Halozone Edge		1.8		3.2		1.8		8.5		3.9		6.6	
	1.5	Halozone		1.8		3.2		1.9		8.8		4.4		6.6	
	0	Center	1.7	1.6	2.1	2.3	2.2	1.9	9.4	8.2	4.8	4.5	6.3	5.7	
Transect 2	25	Upland Marsh	0.8	1.3	1.0	1.3	2.0	1.7	15.0	11.0	7.6	4.7	7.8	8.0	
	15	Halozone Marsh	1.0	1.5	0.5*	1.5	1.8	2.0	11.0	8.3	5.0	4.5	7.0	7.6	
	5.1	Transition	1.8	1.6	1.3	1.9	1.8	2.0	9.8	8.8	4.6	4.6	6.4	7.2	
	4.1	Halozone Edge	1.8	1.6	2.1	1.6	2.3	1.9	9.4	8.5	4.5	4.5	6.7	6.5	
	2.0	Halozone	1.4	1.8	1.4	1.9	2.2	2.3	8.5	8.5	4.6	4.6	6.1	7.1	
	0	Center	1.4	1.7	1.4	2.3	2.1	2.0	7.8	8.7	4.6	4.7	6.4	6.2	
Transect 3	0	Center		2.1		3.7		2.3		11.0		1.6		5.8	
	2.5	Halozone		3.0		4.2		2.7		11.0		1.9		5.7	
	9	Halozone Marsh		2.3		4.0		1.9		10.0		1.6		6.5	

*Interference during analysis

TABLE 2. Importance value by zone of vegetation in the salt marsh along transects 1 and 2. Where distance from source differs from Transect 1, Transect 2 is in parentheses.

Species	Overall Marsh	Upland Marsh	Halozone Marsh			Halozone
			Trsct 1	Trsct 2	Transition	
<i>Aster simplex</i>	64.4	59.6	89.5	59.9	63.3	39.0
<i>Carex lacustris</i>	43.9	57.1	20.2	55.6	10.7	—
<i>Calamagrostis canadensis</i>	34.7	58.6	18.8	7.2	15.5	—
<i>Typha latifolia</i>	13.9	—	29.0	21.4	15.5	5.9*
<i>Scirpus americanus</i>	9.6	—	11.4	2.6	54.4	83.8
<i>Eupatorium perfoliatum</i>	8.9	—	5.2	27.1	9.2	13.0
<i>Hierochloa odorata</i>	7.0	6.5	4.5	11.3	4.9	—
<i>Carex sartwellii</i>	5.8	3.7	2.6	2.2	26.4	—
<i>Eupatorium maculatum</i>	4.2	8.5	9.1	—	—	—
<i>Mentha arvensis</i>	3.4	5.2	6.9	—	—	—
<i>Acorus calamus</i>	1.7	—	—	6.8	—	—
<i>Atriplex patula</i> var. <i>hastata</i>	1.3**	—	—	5.3	—	—
<i>Lycopus uniflorus</i>	0.6	—	2.4	—	—	—
<i>Eleocharis parvula</i>	—	—	—	—	—	28.7
<i>Scirpus olneyi</i>	—	—	—	—	—	12.0
<i>Typha angustifolia</i>	—	—	—	—	—	10.8
<i>Samolus floribundus</i>	—	—	—	—	—	7.0
Distance from source (m)	3(5)–25	16–25	6–16	7–16	3(5)–6(7)	0–3(5)
Total percent cover	174.5	212.2	129.0	172.6	154.2	109.6

*May be *Typha angustifolia*.

**Actually commoner in halozone.

appear in this zone. Cover by *Carex lacustris*, and total vegetative cover, is lower in Transect 1.

In the transition zone between halozone and the rest of the marsh, cover by *Scirpus americanus* increases dramatically. Though important in the rest of the marsh, *Carex lacustris*, *Calamagrostis*, and *Typha latifolia* are at low levels. These species disappear altogether in the halozone. (Vegetative portions of *T. angustifolia* here may have been misidentified at *T. latifolia*.) *Aster simplex* declines as *Scirpus americanus* and the halophytes, *S. olneyi* and *Eleocharis parvula*, assume dominance. Eight vascular plant species are restricted to the halozone (Table 3). Moreover, 15 of 27 species in the rest of the marsh do not grow in the halozone. Vegetative cover in the halozone is the lowest in the marsh.

TABLE 3. Abundance of species growing in the marsh and halozone.

Species	Abundance		
	Marsh	Halozone Edge	Halozone
<i>Aster simplex</i>	dominant	local dominant	
<i>Carex lacustris</i> *	dominant	local dominant	
<i>Calamagrostis canadensis</i>	local dominant		
<i>Iris virginica</i>	local dominant	local dominant	
<i>Typha latifolia</i>	local dominant		common**
<i>Acorus calamus</i>	common		uncommon
<i>Carex sartwellii</i>	common		
<i>Eupatorium maculatum</i>	common		
<i>Eupatorium perfoliatum</i>	common	locally common	
<i>Mentha arvensis</i>	common		uncommon
<i>Rumex orbiculatus</i>	common	locally common	
<i>Scirpus americanus</i>	common		dominant
<i>Cuscuta</i> sp.	uncommon	uncommon	
<i>Hierochloa odorata</i>	uncommon		
<i>Lycopus uniflorus</i>	uncommon		
<i>Onoclea sensibilis</i>	uncommon		
<i>Typha angustifolia</i>	uncommon		uncommon
<i>Scirpus fluviatilis</i>	local, uncommon		
<i>Thelypteris palustris</i>	local, uncommon		
<i>Asclepias incarnata</i>	rare		
<i>Atriplex patula</i> var. <i>hastata</i>	rare		rare
<i>Carex lasiocarpa</i>	rare		
<i>Dulichium arundinaceum</i>	rare		
<i>Equisetum pratense</i>	rare		
<i>Erechtites hieracifolia</i>	rare	rare	
<i>Fraxinus pennsylvanica</i>	rare		
<i>Galium obtusum</i>	rare		
<i>Lysimachia nummularia</i>	rare		
<i>Ranunculus septentrionalis</i>	rare		
<i>Scirpus acutus</i>	rare		
<i>Solanum dulcamara</i>	rare		
<i>Urtica dioica</i>	rare		
<i>Eleocharis parvula</i>			local dominant
<i>Scirpus olneyi</i>			local dominant
<i>Eleocharis</i> cf. <i>E. erythropoda</i>			locally common
<i>Samolus floribundus</i>			locally com- mon/uncommon
<i>Sium suave</i>			uncommon
<i>Alisma plantago-aquatica</i>			rare
<i>Phragmites australis</i>			rare
<i>Portulaca oleracea</i>			rare

*May include *Carex sartwellii*.**May be *Typha angustifolia*.

DISCUSSION

Wetlands of the upper Midwest have naturally low concentrations of Na^+ , Cl^- , and K^+ and, except in bogs, fairly high concentrations of Ca^{++} and Mg^{++} . Groundwater samples taken from northern Lower Michigan wetlands (bogs, fens, swamps and marshes) show ionic concentrations of 0.0017–0.0034 g/l Na^+ , 0.00015–0.0043 g/l Cl^- , 0.0005–0.001 g/l K^+ and, except in bogs, 0.041–0.0836 g/l Ca^{++} and 0.0121–0.0162 g/l Mg^{++} (Schwintzer & Tomberlin 1982). By contrast, sea water contains 10.56 g/kg Na^+ , 18.98 g/kg Cl^- , 0.38 g/kg K^+ , 0.40 g/kg Ca^{++} , and 1.27 g/kg Mg^{++} (Braitsch 1971). Although comparison of these ionic concentrations in solution to soil samples cannot be direct, Na^+ , Cl^- , and K^+ are plainly more concentrated in the salt marsh than in northern wetlands but, except for K^+ , much less than in sea water.

Bill Walden, Michigan DNR Geology Division, confirms that Na^+ , Cl^- , and K^+ originate in saline aquifers. The ions move to the surface in water forced upward by hydrostatic pressure. Where glacial drift is thin (along rivers, on post-glacial lakebeds, etc.) saline water can emerge as a discrete spring or seep. The changes in species cover and presence along the salinity gradient in the salt marsh strongly suggest the halozone is the major source at least of Na^+ and Cl^- ; K^+ increases comparatively little along the transect and may enter the marsh in groundwater as well. There may be smaller seeps outside the halozone—for instance, in the halozone marsh along Transect 1 where high Na^+ concentration diminishes cover by causing the relatively salt-intolerant *Carex lacustris* and *Calamagrostis canadensis* to decline.

Ca^{++} and Mg^{++} are highly concentrated in the salt marsh compared to both northern wetlands and sea water. Calcium and magnesium carbonates principally derive from calcareous glacial deposits in southern Lower Michigan. The salinity gradient in the salt marsh strongly suggests that Ca^{++} and Mg^{++} originate primarily in glacial material. Evidently Ca^{++} also enters at the saline seep in the halozone marsh along Transect 1 and at the center of the halozone where, downslope, its concentration is high along Transect 3. Brines of the Michigan basin are calcium-rich and magnesium-poor, according to David Long, Michigan State University Dept. of Geology, but this calcium may also derive from Saginaw or Bayport Limestone Formations lying up to 1130 feet below glacial material (Dorr & Eschman 1970).

Ionic concentration in the halozone or at its edge exceeds that at the halozone center. This zone of salt deposition may result when saline water spreads from the halozone seep outward, then evaporates and concentrates salts in the soil. Salt deposition could take place in dry periods when the seep saturates the halozone, leaving standing water in small depressions. But floods (nearly an annual event, says Richard Sorrell, Michigan DNR Water Management Division) and heavy rains lessen the effect of the seep by diluting it, as Houghton (1837) also discovered.

When Houghton visited the salt marsh he saw a spring from which he drew samples for analysis. Reduction of regional aquifers most likely

changed this spring to a seep, although well drilling in 1838 could have disrupted spring flow. Houghton's spring samples diluted by floodwater contained 1.039 g/l Na^+ , 1.748 g/l Cl^- , 0.233 g/l Ca^{++} , and 0.083 g/l Mg^{++} . Na^+ and Cl^- are proportionally much less than Ca^{++} and Mg^{++} in present samples than they were in Houghton's day, suggesting that the brine may be weaker. In addition, the halozone may be smaller today because less brine is delivered to the salt marsh by the present seep than by the former spring.

ACKNOWLEDGMENTS

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REVIEW

WILDFLOWER IDENTIFICATION KIT. A computer program written by Ed Byrnes. Available from Intuitive Logic, 412 Taylor Street, Rochester, MI 48063-4327. \$59.95 post-paid. Computer system requirements: a Zenith Z-100 computer (192K RAM and color memory chips), Z-DOS, and Z-BASIC; RGB color monitor recommended.

Most previous efforts using computers to aid in plant identification, here at Michigan State University and elsewhere, have involved mainframe computers. The increasing popularity of personal computers has brought attempts to use the smaller machines to achieve similar tasks. This *Wildflower Identification Kit* is the first such commercial product we have seen for an MS-DOS microcomputer. The purchaser receives two double-sided, double density diskettes, a five page booklet, and a copy of Fassett's *Spring Flora of Wisconsin* (Fassett, 1976).

The program diskettes are not copy-protected and instructions for making backup copies of the program for use with Z-DOS are provided. We found that the program will run under MS-DOS 2.0, but the copying procedure must be somewhat modified. After two introductory displays, the program presents a series of questions. The user has the choice of answering "Yes" or "No" to each question, asking for a definition from the glossary or a "picture", backing up to the beginning of a section of the key, or restarting the program. The glossary, taken from Fassett, contains 276 common botanical terms. The pictures illustrate a regular hypogynous flower (with floral parts labeled), common inflorescence types, leaf types, and leaf shapes. Except for a short section in the first part of the program which leads to three parasitic taxa, the questions are based on the introductory keys in Fassett. These keys lead in most cases to a family name, occasionally directly to a genus; reference to the appropriate page in Fassett is sometimes given with the identification. The book must be used to identify a plant to the species level.

We found that most of the program works as designed. There are some mistakes in the version we tested that could be easily corrected by the author. For this review, we will concentrate on the botanical aspects of the program; additional comments on program structure are available from us.

It is not obvious to the user that, by answering the questions, a choice is actually being made between leads of couplets. Consider these adjacent questions:

Stems woody (Y/N)?

Stems not woody (Y/N)?

Program design dictates that the user, if answering "no" to the first question, must enter "yes" to the second question, even though "yes" is logically implied from the context of the initial "no" entry. The questions are not presented so that couplets can be easily recognized; conventions used in most printed keys, such as numbers or indentation, are missing. After answering many undifferentiated questions, we became frustrated with this format. We think that emphasizing the inherent couplet structure and having the program make the implicit "second yes" assumption would improve the program.

We found that having the glossary and pictures available at any time was convenient. Unfortunately, there is a problem with using the glossary in that lower case entries of words beginning with a-f are not accessible due to a subtle oversight in program logic. Several typographical errors were noted; some (e.g. primocane spelled as "pimocane") will not allow the user to find certain definitions. The pictures included are detailed and useful, giving the user an excellent graphic representation of the illustrated plant structures. Except for some blue and purple leaves, color has been used effectively to enliven the pictures. Given the author's obvious talent for creating such displays, the program would be more impressive if it included additional pictures, e.g. epigynous and zygomorphic flowers.

We are disturbed by the author's claim that the kit will "enable the user to identify at least 90% of the wildflowers and trees east of the Mississippi River" (Byrnes, 1985). Making such a claim in light of the limited scope of Fassett's *Spring Flora of Wisconsin* is misleading. Fassett excluded ferns and conifers; this may cause problems for the beginner where these plants are abundant. The restriction to plants found in Wisconsin reduces the usefulness of the kit; in some areas, genera or even entire families will be missing, e.g. southern forests (Calycanthaceae, Magnoliaceae, Styracaceae), boreal habitats (Empetraceae), and even southern Michigan for-

ests (*Asimina*, *Lindera*, *Liriodendron*, *Sassafras*). Another major limitation is that Fassett's keys for some common trees (e.g. *Acer*, *Betula*, *Fagus*, and *Quercus*) require floral characters that are only present for a short time during the year.

The author also claims "you will be able to identify wildflowers found all summer long" (Byrnes, 1985). This is probably accurate for some common species, but not for the majority which flower for only a short period. Some genera have early and late flowering members—early ones are in Fassett but late ones are not: *Verbascum blattaria* is included while *V. thapsus* is not; non-native *Hieracium* species are included whereas all native taxa are excluded. The late summer collector would face severe handicaps since there are many genera (e.g. *Andropogon*, *Aster*, *Cichorium*, *Cirsium*, *Daucus*, *Epilobium*, *Eupatorium*, *Gentiana*, *Solidago*, *Sorghastrum*) and families (Alismataceae, Amaranthaceae, Chenopodiaceae, Dipsacaceae, Droseraceae, Hamamelidaceae, Phytolaccaceae, Pontederiaceae, Potamogetonaceae, Typhaceae) likely to be encountered that are not mentioned in the book, and thus, are not in the key.

It is difficult to be sure of the intended audience for this package. One advertisement for the kit states it includes "everything you need to know to collect and identify wildflowers . . ." (Sextant, May–June 1985, p. 34). Although the booklet explains the use of Fassett's *Flora* and the program, with some very general information on finding and collecting wildflowers, we feel that additional information needs to be provided for the beginner. Simply referring the novice to a brief list of references and/or a university "local flora" course is hardly adequate. Preservation of collected specimens for future study is not discussed. Neither cautions about handling, nor clues for recognizing, potentially injurious plants (such as poison ivy) are given. No mention is made of rare, endangered, and legally-protected plants, a potential problem in light of the author's suggestion to collect any plant to be identified. On the other hand, botanists familiar with computer-assisted identification approaches which allow entry at any couplet (e.g. Morse, 1974) may question whether the program offers any clear advantage over using Fassett alone.

We think that this program may be of interest, not only to the individual wildflower enthusiast, but also as a teaching tool in secondary and post-secondary biology and botany courses. However, considering the errors that exist in the version we tested, the program needs further refinement before we can wholeheartedly recommend it. Furthermore, we feel the author should lessen his claims for the program in light of the botanical limitations discussed above. The author has effectively used the high-resolution color graphics available on the Zenith Z-100 microcomputer to produce detailed, colorful displays. This computer is not as widely used as other micros, restricting the market for the kit. Based on our study of the readily-accessible program code, it should be possible for the author to convert the graphics parameters to allow the program to run on most IBM-compatible PC's (though the quality of the illustrations would be lessened), widening the market for this product significantly.

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NEW RECORDS FOR SPHAGNUM IN INDIANA

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The only previous bryological treatment specifically noting *Sphagnum* species for Indiana (Welch, 1957) follows the taxonomy of the conservative Andrews (1913) monograph and lists 11 taxa—nine species and two varieties. One of these varieties, *Sphagnum imbricatum* var. *affine* (Ren. & Card.) Warnst. is not recognized by most authorities. Although several additional species records can be found by a careful reading of several monographs (Andrus, 1980a; Crum, 1984), our recent collecting and herbarium work has raised the list to a total of 28 species with seven of these alone coming from two sites apparently overlooked in the past. Taxonomy is according to Andrus (1980a).

S. centrale C. Jens. LAKE CO., Glen Park, *Hill 27-1910* (C); PORTER CO., Dune Park, *Hill 291-1907* (C, ILL), *187-1908* (C); PUTNAM CO., 10 km WSW of Greencastle, *Horton 21820* (BING, IA).

S. magellanicum Brid. LAPORTE CO., Pinhook Bog, *Andrus 5667* (BING); PUTNAM CO., 10 km WSW of Greencastle, *Horton 21832* (BING, IA). Reported by Welch for Fulton, Kosciusko, Noble, and Porter Counties. Some of these records may be referable to *S. centrale* as these two were combined by Andrews (1913).

S. henryense Warnst. Previously reported for LaGrange, Lake, Marshall, and Porter Counties in Andrus (1980b).

S. palustre L. Reported by Welch for 15 counties but not seen by us. Some of the records for this species are likely referable to *S. henryense* (Andrus, 1980b).

S. imbricatum Russow. LAPORTE CO., Pinhook Bog, *Andrus 5679* (BING); MONROE CO., S of Bloomington, *Rayburn VII-17-1963* (MO). Also reported by Welch for LaGrange, Lawrence and Porter Counties.

S. papillosum Lindb. LAPORTE CO., Pinhook Bog, *Andrus 5684* (BING).

S. compactum DC. Reported by Welch for Cass, Jasper, and Jefferson Counties. The Cass and Jefferson County locations have been verified.

S. squarrosum Crome. LAKE CO., Tolleston area, Gary, *Steyermark 68202* (C); LAPORTE CO., Pinhook Bog, *Andrus 5690* (BING); PORTER CO., T37N, RGW, Sect. 22, *Wilcox 16XD* (BING); PUTNAM CO., 10 km WSW of Greencastle, *Horton 21826* (BING, IA).

S. teres (Schimp) Angstr. LAKE CO., S of Miller, *Hill 199-1908* (C, ILL); LAPORTE CO., Pinhook Bog, *Andrus 5675* (BING).

S. lescurii Sull. Jefferson Co., 5 km S of Hanover, *Welch* 5233 (IND).

S. contortum K. F. Schultz. LAKE CO., Liverpool. *Standley* 57175 (C), 92852 (C); PORTER CO., Willow Creek Station, *Hill* 112-1909 (ILL), T37N, R6W, Sec. 22, *Wilcox* 16XJ (BING).

S. platyphyllum (Braithw.) Warnst. PORTER CO., T37N, RGW, Sect. 22, *Wilcox* 16XE (BING).

No material referable to *S. subsecundum* Nees. *sensu stricto* has been seen. Welch reported *S. subsecundum* for eight counties but the material could not be located. Most of these are likely to be other segregates of *S. subsecundum* *sensu lato*, though *S. subsecundum* *sensu stricto* could still be expected to occur in the state.

S. cuspidatum Hoffm. LAKE CO., Grant Township, *Hill* 243-1908 (ILL); PORTER CO., Dune Park, *Hill* 136-1908 (C, ILL), N of Michigan City, *Hill* 78-1908 (C, ILL), Pinhook Bog, *Andrus* 5662 (BING).

S. fallax (Klinggr.) Klinggr. LAKE CO., Dune Park, *Hill* 139-1908 (C, ILL), 129-1908 (ILL); PORTER CO., Pinhook Bog, *Andrus* 5665, 5678 (BING).

S. recurvum P. Beauv. LAKE CO., Miller, *Hill* 113-1878 (C, ILL), LAPORTE CO., Pinhook Bog, *Andrus* 5669 (BING); MARSHALL CO., 5-7 km SW of Bremen, *Welch* 2130 (C); PORTAGE CO., NE of Dune Park, *Hill* 99-1909 (ILL), 101-1909 (C, ILL), Pine, *Hill* 209-1906 (C).

S. flexuosum Dozy & Molk. LAKE CO., Miller, *Hill* 113-1878 (C); LAPORTE CO., Pinhook Bog, *Andrus* 5661 (BING); PORTER CO., Dune Park, *Hill* 203-1906, 204-1906 (C).

S. augustifolium (Russow) C. Jens. LAKE CO., Pine Swamp, *Hill* 168-1905 (C, ILL), 274 (ILL); LAPORTE CO., Pinhook Bog, *Sargent* 311x/1981 (BING); PORTAGE CO., Dune Park, *Hill* 208-1906 (C, ILL); PUTNAM CO., 10 km WSW of Greencastle, *Horton* 21820 (BING, IA).

S. pulchrum (Braithw.) Warnst. LAPORTE CO., Pinhook Bog, *Sargent* 311x/1981 (BING).

S. riparium Angstr. LAPORTE CO., Pinhook Bog, *Andrus* 5688 (BING).

S. capillifolium (Ehrh.) Hedw. (= *S. nemoreum* Scop.) LAPORTE CO., Pinhook Bog, *Wilcox* 7 (BING); PUTNAM CO., 10 km WSW of Greencastle, *Horton* 21829, 21842 (BING, IA).

S. subtile (Russow) Warnst. PORTAGE CO., SE of Dune Park, *Hill* 114 (F).

S. rubellum Wils. PUTNAM CO., 10 km WSW of Greencastle, *Horton* 21825 (BING, IA).

S. bartlettianum Warnst. LAPORTE CO., Pinhook Bog, *Andrus* 5660, 5687 (BING). The occurrence here of *S. bartlettianum* is surprising in view of its previously presumed southeastern coastal plain distribution (Andrus, 1979). Its occurrence here with two other "coastal plain" species, *S. recurvum* s. s. and *S. henryense*, means that for *Sphagnum* distribution the coastal plain, in the broad sense, must be presumed to include the Great Lakes plain (cf Fernald, 1937; Andrus, 1974).

S. fuscum (Schimp.) Angstr. PUTNAM CO., 10 km S of Greencastle, *Horton* 21824 (BING, IA).

S. girgensohnii Russow. LAKE CO., Deep River, *Hill 119-1906* (ILL). Also reported by Welch for LaPorte and Wells counties.

S. russowii Warnst. LAKE CO., Deep River, *Hill 119-1903* (C), *120-1903* (ILL); PORTER CO., Willow Creek, *Hill 113-1909* (ILL); PUTNAM CO., 10 km WSW of Greencastle, *Horton 21823* (BING, IA).

S. fimbriatum Wils. LAKE CO., Liverpool, *Hill 128-1903* (ILL), *206-1904* (C, ILL); LAPORTE CO., Pinhook Bog, *Andrus 5666* (BING), Cowles Bog, *Andrus 5693* (BING); PORTER CO., T37N, RGW, Sect. 22, *Wilcox 16XH* (BING); PUTNAM CO., 10 km SWS of Greencastle, *Horton 21819* (BING, IA). Also reported for Elkhart Co. by Welch.

S. wulfianum Girg. PUTNAM CO., 10 km WSW of Greencastle, *Horton 21840* (BING, IA).

Sphagnum fuscum, *S. rubellum* and *S. wulfianum* have been found only in one location in Indiana, an abandoned sandstone quarry near Greencastle. What makes this site so special is not only the unusual species occurring there but also the fact that these species appear to have become established very recently (Sargent, pers. comm). The quarry was abandoned around 1910, but there is reason to believe that as recently as 20 years ago *Sphagnum* was scarce or absent. Though the constant seepage of water over poorly drained sandstone creates excellent conditions for *Sphagnum*, the apparent rapidity with which so many species, ten *Sphagna* in all, have become established has interesting implications for mire succession.

A parallel case in northeastern Ohio has recently been documented in some detail (Andreas and Host, 1982). There a peat mat has also developed in a recently abandoned sandstone quarry. The predominance of *Sphagnum teres* (Schimp.) Angstr. as well as a pH of 5.2 and a specific conductance of 168 $\mu\text{mhos/cm}$ would class this site as a medium fen. Although some parts of the fen mat portion were abandoned only 40 years ago, 56 ha of mat had formed there by 1982 with at least five *Sphagnum* species present. The estimated peat accumulation rate of up to 0.43 cm/yr considerably exceeds most estimates for peat formation and has produced a mat of 60 cm in depth in some areas. A quantitative investigation of the Indiana site, a poor fen, could yield some good comparative insights.

Sphagnum papillosum, *S. pulchrum*, and *S. riparium* are known only from Pinhook Bog, another quite unusual site. Pinhook Bog is located in LaPorte County in northwestern Indiana and occupies an ice block depression in the Valparaiso Moraine, deposited by the retreating Wisconsin age glacier. It is included within the authorized boundaries of Indiana Dunes National Lakeshore. The basin of the 44 hectare bog is seated in a sandy clay glacial till and consists of three major lobes, the deepest of which extends 18 m below the bog surface (Wilcox, unpublished). The surface of the bog is totally covered by a peat mat, much of which is floating, yet there are numerous small, shallow ponds which represent recessions in the mat. As a result of the isolation from groundwater flows, low mineral concentration/low pH conditions occur throughout much of the bog (Table 1). Runoff from the limited watershed has created a more minerotrophic moat surrounding the bog, and atmospheric inputs from adjacent agricultural lands and regional industrialization may also have influenced bog water chemistry.

TABLE 1. Mean water chemistry determinations for all interstitial water sampling sites on control transect, Pinhook Bog, 1980-82¹.

Indicator	Mean	Std. dev.	No. samples
pH (units)	3.68	—	69
Specific conductance (µmhos/cm)	64	17	69
	Concentration (mg/l)		
Acidity as CaCO ₃	67	32	60
Alkalinity as CaCO ₃	0.0	0.0	60
Chloride	5.9	2.7	76
Sodium	1.9	1.0	22
Potassium	0.9	0.4	22
Calcium	2.7	1.0	21
Magnesium	1.6	0.5	21

¹from Wilcox (1982)

The dominant tree species in Pinhook Bog is *Larix laricina* (tamarack). The tall shrubs are dominated by *Vaccinium corymbosum* (highbush blueberry), *Gaylussacia baccata* (huckleberry), and *Pyrus floribunda* (purple chokeberry) and the smaller shrubs by *Chamaedaphne calyculata* var. *angustifolia* (leatherleaf) and *Vaccinium oxycoccos* (small cranberry). The prevalent herbaceous species include *Carex trisperma* (three-fruited sedge), *Rhynchospora alba* (white beakrush), *Drosera intermedia* (narrow-leaved sundew), *Sarracenia purpurea* (pitcherplant), and *Cypripedium acaule* (stemless lady's slipper). *Sphagnum* provides the overwhelming groundcover on the mat (Wilcox, 1982). The plant associations occur in mosaics rather than concentric zones, with the absence of tree and high shrub cover near the small ponds apparently playing a determining role.

The presence of a diversity of higher plants and a significant number of *Sphagnum* species (16) in Pinhook Bog may relate to climate, phyto-geographic location, and human disturbance. Pinhook Bog is probably the southernmost mineral-poor peatland in the midwest glaciated area and likely has warmer temperatures and a longer growing season than bogs of more northerly latitudes. The vegetation of the Indiana Dunes region is known as a crossroads for boreal relics, Atlantic coastal plain disjuncts, Great Lakes endemics, southern species at their northern limits, and prairie species at their eastern limits. Impacts of highway de-icing salts on bog water chemistry in a 2 hectare portion of the bog have been documented, as have subsequent alterations of the vegetation (Wilcox, 1982).

S. platyphyllum has been found in only one location, an intradunal pond in Porter County, where it occurs in association with *S. contortum*, *S. fimbriatum*, and *S. squarrosum*. The pond experienced artificially high water levels from industrial activity from the mid-1960's through 1980. Following cessation of these activities, the water level has dropped and a heavy invasion of *Typha* and other emergents has occurred which affect the long term survival of these ruderal *Sphagnum* species.

Nearly all of the new state records reported here are for essentially northern species from Lake, Porter, and LaPorte counties, the three northern tier counties bordering Lake Michigan. Besides the three species known only from Pinhook Bog, *S. teres*, *S. contortum*, *S. platyphyllum*, *S. cuspidatum*, *S. fallax*, *S. flexuosum*, and *S. subtile* are also limited to the three lake edge counties. All of these are near or at their southern range extremes here for interior North America. The basic reason for this may be at least as much habitat availability as climate. Poorly drained, wet, acidic sites are ideal for mire formation, and in Indiana such sites occur naturally mainly in the sandy substrates of the northern counties. That this is so is indicated by the seemingly disjunct appearance of *S. centrale*, *S. squarrosum*, *S. angustifolium*, *S. capillifolium*, *S. russowii*, and *S. fimbriatum* at the abandoned sandstone quarry in Putnam County, about 200 kilometers by airline south of the northern counties. Even more unusual, the Putnam County site also contains three northern species *S. rubellum*, *S. fuscum* and *S. wulfianum*—that occur nowhere in the state. Equally perplexing is the fact that of these three only *S. fuscum* bears sporophytes with any frequency. Apparently the abandoned quarry represents a human-created habitat well suited for *Sphagnum* establishment and growth and, either by spores or vegetative fragments, at least ten species have become established, most of them quite disjunctive. Habitat, not climate, seems at present to be the principal factor limiting *Sphagnum* distribution in Indiana.

It should also be noted that the records for *S. henryense*, *S. recurvum*, and *S. bartlettianum* are all at, or near, the northern range extreme for species that, in eastern North America, are basically southern and coastal.

SUMMARY

The Indiana *Sphagnum* flora is expanded from 10 to 28 species. *Sphagnum henryense*, *S. recurvum*, and *S. bartlettianum* are more southerly species reaching northern limits while *S. centrale*, *S. papillosum*, *S. squarrosum*, *S. teres*, *S. contortum*, *S. platyphyllum*, *S. fallax*, *S. flexuosum*, *S. angustifolium*, *S. pulchrum*, *S. riparium*, *S. capillifolium*, *S. subtile*, *S. rubellum*, *S. fuscum*, *S. girgensohnii*, *S. russowii*, *S. fimbriatum*, and *S. wulfianum* are northern species which reach a southern limit in Indiana. One half of the northern species are limited to the three northern counties bordering Lake Michigan, but the occurrence of the other half in an apparently recently colonized abandoned sandstone quarry in the middle of the state suggests that the limiting factor may be habitat more than climate. The most extensive peatland in the state, Pinhook Bog, is briefly characterized.

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Editorial Notice: List of Reviewers

We wish to thank those people who have provided reviews of the papers published in volume 24 (1985). Their comments have helped us do our job as editors and have helped the authors prepare clear and useful articles. We gratefully acknowledge their contribution.

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A CHECKLIST OF BRYOPHYTES AND THEIR CRITICAL LOCALITIES IN THE KEWEENAW PENINSULA, MICHIGAN.

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Wells and Thompson (1974) have reviewed several important habitats for Keweenaw County and pointed out the uniqueness of the flora relative to the rest of the state. The geological history and climate of the Keweenaw Peninsula, combined with minimal recent disturbance, provide a haven for many plants, including bryophytes, which occur nowhere else in the state. The geology is characterized by five parallel conglomerate ridges that extend the length of the Peninsula and slope abruptly into Lake Superior at the tip. Maximum elevation is 467 m (1534 ft.), more than 274 m (900 ft.) above the level of Lake Superior. The vegetation is rich, with dune, bog, and wetland habitats being abundant. Most of the area is covered by forest, with second-growth sugar maple (*Acer saccharum* Marsh.) and mixed coniferous stands being common. Few examples of the mature coniferous forest that prevailed before mining and logging in the late 19th century remain. The climate is northern, with an average yearly range of temperature from -28 to 33°C (-19 to 91°F). Mean minimum and maximum temperatures for July are 12°C (53°F) and 22°C (71°F); for January they are -14°C (6°F) and -4°C (24°F). The growing season is short; the last spring frost occurs near the end of May and the first fall frost comes near the end of September. Mean annual precipitation is 91 cm (36 in.) and average annual snowfall is 5.84 m (230 in.).

Steere (1937) expressed the opinion that the number of species of bryophytes in any one Michigan county probably does not exceed 300. But Keweenaw Peninsula is in a transition zone with boreal, western, and eastern deciduous forest affinities, so a number greater than that might be expected in mainland Keweenaw and adjoining Houghton Counties. For this reason representative Keweenaw Peninsula habitats important to bryophytes deserve some notice. The present paper discusses five locations of bryological interest. None of the locations is legally protected. Two are privately owned and three are owned by Calumet and Hecla Mining Co.

The critical habitats selected here are those which provided the greatest numbers of representatives, particularly of uncommon species, and where bryophytes are the dominant ground cover. All sites lack evidence of recent disturbance. The checklist represents all previous published records plus our own collections and others we were able to find in the major Michigan herbaria. We attempted to relocate specimens of dubious records. The list of excluded names includes species we found misidentified, plus those where

later publications cited errors in identification. Queried records are those we could not verify, for which there is no other nearby record, and which are not supported by any recent publications such as Crum & Anderson (1981). The liverwort list is based on published records, including Schuster (1966, 1969, 1974, 1981), and on an unpublished list compiled by Norton Miller. Since Miller reviewed the Michigan (MICH) collections and is an authority on liverworts, we accepted his list. All records of liverworts reported by us have been seen by us or reported by a contemporary authority. All of the Keweenaw Peninsula species were included by Hollensen (1984) in his checklist of Michigan taxa. Our Keweenaw Peninsula list contains 342 taxa—251 mosses and 91 liverworts.

One surprise among the Keweenaw Peninsula bryophytes is the number of calciphiles. Relative to the Lower Peninsula of Michigan, the Keweenaw area is acidic. Exposed rock is usually Jacobsville sandstone or basalt. However, conglomerates with mixed rock types occur, and it is possible that the glacier deposited localized pockets of alkaline rock suitable for small clumps of calciphilic bryophytes. Such obligate calciphiles as *Seligeria* and *Didymodon* are conspicuously absent.

In striking contrast to the Lower Peninsula, *Fontinalis* occurs in many Keweenaw streams. Seven taxa, with an eighth in nearby Marquette Co., apparently represent the greatest concentration of *Fontinalis* taxa anywhere in the world. In the Lower Peninsula there are almost no records of the genus. Although the number of taxa is great, *Fontinalis* is rarely abundant in Keweenaw streams. Perhaps this is partly due to the scarcity of suitable rocky substrates, a limiting factor that is important in excluding the genus in the Lower Peninsula. But a major factor limiting its abundance in the Keweenaw Peninsula is likely to be the tremendous disturbance in the mining days.

The current lack of vast disturbed areas is reflected by the paucity of disturbed habitat invaders. *Physcomitrium pyriforme* and *Trematodon ambiguus* were just recently reported for the first time (Glime 1982), and ephemerals are notably absent from the record, perhaps in part because there have been so many more interesting habitats to explore.

The following habitats typify the critical bryophyte habitats of the Peninsula. In addition, the summit of Lookout Mountain has unusual calciphiles (Glime et al. 1980) and the Dow Wilderness area has a well-developed epiphyte flora (Trynoski & Glime, 1982). Other habitats, such as sand dunes and roadsides, were explored, but no unusual species were located. The ephemeral habitats yield interesting species but hardly justify inclusion as critical because of their short-term existence. Wetland and bog areas have been ignored here because a more comprehensive description of these areas is planned.

The Manganese Falls, on the Manganese River between Lake Manganese and Lake Fanny Hoe (47° 30'N, 85° 50'W, T59N, R28W, sec. 32), drop into a deep gorge where the light is subdued and the air is continuously cool and moist. Substrates of soil and conglomerate cliffs and ledges support a number of northern bryophytes (as already noted by Steere, 1938). On a one-day trip we found 47 mosses and liverworts in the gorge and trailside,

and eight species were added from Margaret Feigley's collections below the gorge (MCTC). Of these, 11 are new for the Peninsula.

The rocky shore of Lake Superior, 0.8 km northeast of Cat Harbor (47° 25' 30''N, 88° 13' 3''W, T58N, R31W, sec. 1), offers several rare northern species in a cold, windswept habitat. The habitat can be extremely dry or very wet and is subject to crashing ice and scouring. Nevertheless, we found 40 mosses and 9 liverworts. These furnished 11 new records of mosses and one liverwort for the Peninsula.

Jacob's Creek Falls, just southeast of M-26 (47° 25'N, 88° 15'W, T58N, R31W, sec. 15-16), emerge from a deep gorge of basaltic rock and high humidity. Cool temperatures in the gorge maintain a climate favoring many northern species. After numerous collecting trips we recorded 55 species of bryophytes in the gorge and 59 in the forest surrounding it, with 81 mosses and 22 liverworts in all. This area appears to have been missed by earlier collectors and has several noteworthy species, including 18 Keweenaw Peninsula records.

The talus slopes on Cliff Drive are located 5.4 km north of Seneca Lake on the west side of Cliff Drive (47° 20'N, 88° 20'W, T57N, R32W, sec. 2). The huge boulders begin in the forest and rise up onto the steep cliffs. The boulders provide numerous small caves where ice persists long past melting season, and habitat diversity abounds. Although between us we have visited the area about 10 times and led the Midwest bryological foray here [Glime et al. 1982], each visit has produced more species. The area surveyed is scarcely more than 100 m in any direction, but we have found 24 liverwort and 104 moss species. Steere (1937) remarked on the rich bryophyte flora at Cliff. Ferns are abundant and varied as well. Thirty-two new moss and five new liverwort records for the Peninsula are reported here, two of them being new Upper Peninsula records as well. Three of the mosses are known in Michigan only from Keweenaw Co.: *Orthotrichum alpestre*, *Pseudoleskea radicata*, and *Rhytidium rugosum*.

Gooseneck Creek has cliffs of Jacobsville sandstone which face northeast and southwest above the Y formed by Gooseneck Creek in Dollar Bay, Houghton Co. (47° 6'N, 88° 30'W, T55N, R33W, sec. 28). The southwest-facing cliffs are a combination of sandstone and soil and are usually shaded by the forest, whereas the northeast cliffs have vertical rock which shades itself. The multitude of habitats supports 25 liverworts and 78 mosses. Little collecting has been reported from Houghton Co.; we could find only 6 liverworts and 77 mosses in the literature. This report adds 23 liverwort and 48 moss records to the county, including 22 mosses and 9 liverworts for the Keweenaw Peninsula. *Calypogeja fissa* is new for the Upper Peninsula. This marks the southernmost location for *Andreaea rupestris* in Michigan.

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Steere, Dale Vitt, William Zales, and Richard Zander. Specimens and records were contributed by Margaret Feigley and Fred Hermann. The University of Michigan Herbarium and the Beal-Darlington Herbarium provided specimens on loan. We thank Janet Marr for locating the Houghton and Keweenaw Co. specimens in the Beal-Darlington Herbarium at Michigan State University. Voucher specimens of new records are in the Michigan Technological University Cryptogamic Herbarium. Nomenclature for mosses follows Crum & Anderson (1981); for liverworts it follows Stotler & Crandall-Stotler, 1977.

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CHECKLIST OF KEWEENAW PENINSULA BRYOPHYTES

Mosses

<i>Amblystegium fluviatile</i> (Hedw.) Loeske	H K	J		
<i>A. riparium</i> (Hedw.) Warnst.	H K		D	
<i>A. serpens</i> (Hedw.) BSG	H K			
<i>A. tenax</i> (Hedw.) Jenn.	H +		G	
<i>A. trichopodium</i> (Schultz) Warnst.	K			
<i>Amphidium lapponicum</i> (Hedw.) Schimp.	H K	M	J D	
* <i>Anacamptodon splachnoides</i> (Froel.) Brid.	K		D	
<i>Andreaea rupestris</i> Hedw.	H K		D G	
<i>Anomodon attenuatus</i> (Hedw.) Hueb.	H K	M	J D	
<i>A. rostratus</i> (Hedw.) Schimp.	H K	M	J G	
* <i>A. rugelii</i> (C. M.) Keissl.	K		D	
<i>A. viticulosus</i> (Hedw.) Hook. & Tayl.	?			
* <i>Atrichum crispum</i> (James) Sull.	K			
<i>A. undulatum</i> var. <i>altecristatum</i> Ren. & Card.	H K		J D G	
<i>Aulacomnium palustre</i> (Hedw.) Schwaegr.	H K			
<i>Barbula convoluta</i> Hedw.	H K		D G	
* <i>B. unguiculata</i> Hedw.	H K		D	
<i>Bartramia ithyphylla</i> Brid.	+			
<i>B. pomiformis</i> Hedw.	H K		J D G	
<i>Blindia acuta</i> (Hedw.) BSG	K	C		
<i>Brachythecium acuminatum</i> (Hedw.) Aust.	H K		G	
<i>B. calcareum</i> Kindb.	+ K		D	
* <i>B. campestre</i> (C. M.) BSG	H K	M	G	
* <i>B. curtum</i> (Lindb.) Limpr.	H K		D	
* <i>B. digastrum</i> C. M. & Kindb.	K		D	
<i>B. oxycladon</i> (Brid.) Jaeg. & Sauerb.	K		J D	
<i>B. plumosum</i> (Hedw.) BSG	K	C	J D	
* <i>B. populeum</i> (Hedw.) BSG	H K	M	J D G	
<i>B. reflexum</i> (Starke) BSG	H K	M C	J D G	
<i>B. rivulare</i> BSG	H K	M	J D G	
<i>B. rutabulum</i> (Hedw.) BSG	H K	M	G	
<i>B. salebrosum</i> (Web. & Mohr) BSG	H K		J G	
* <i>B. turgidum</i> (C. J. Hartm.) Kindb.	K	C		
<i>B. velutinum</i> (Hedw.) BSG	K		J D	
* <i>Brotherella recurvans</i> (Mx.) Fl.	H K		J D G	
* <i>Bryhnia graminicolor</i> (Brid.) Grout	H K	M	G	
<i>B. novae-angliae</i> (Sull. & Lesq.) Grout	H +		G	
* <i>Bryoerythrophyllum recurvirostrum</i> (Hedw.) Chen	H K	M	J D	
* <i>Bryum argenteum</i> Hedw.	H K		D	
* <i>B. caespitium</i> Hedw.	K		J	
<i>B. capillare</i> Hedw.	H K		J G	
* <i>B. lisae</i> var. <i>cuspidatum</i> (BSG) Marg.	H K		D	
* <i>B. pallens</i> (Brid.) Sw.	K			
<i>B. pseudotriquetrum</i> (Hedw.) Gaertn. et al.	H K		J	
* <i>B. weigelii</i> Spreng.	K			
* <i>Buxbaumia aphylla</i> Hedw.	H		G	
<i>Callicladium haldanianum</i> (Grev.) Crum	H K		J D G	
* <i>Calliergon cordifolium</i> (Hedw.) Kindb.	H K			
* <i>C. giganteum</i> (Schimp.) Kindb.	H K			
<i>C. stramineum</i> (Brid.) Kindb.	H K		D	
* <i>C. trifarium</i> (Web. & Mohr) Kindb.	K			

<i>Calliergonella cuspidata</i> (Hedw.) Loeske	H	+			
<i>Campylium chrysophyllum</i> (Brid.) J. Lange	H	K	M	C	D
<i>C. hispidulum</i> (Brid.) Mitt.	H	K		J	D
* <i>C. stellatum</i> (Hedw.) C. Jens.	H	K			D
<i>Ceratodon purpureus</i> (Hedw.) Brid.	H	K	M	C	J D G
* <i>Climacium dendroides</i> (Hedw.) Web. & Mohr	H	K	M	C	G
* <i>Conardia compacta</i> (C. M.) Robins.	H	K		J	G
<i>Cratoneuron filicinum</i> (Hedw.) Spruce		K	M		
* <i>Cynodontium alpestre</i> (Wahl.) Milde	H	K		C	D G
* <i>C. schisti</i> (Web. & Mohr) Lindb.	H				G
* <i>C. strumiferum</i> (Hedw.) Lindb.		K		C	D
* <i>Desmatodon obtusifolius</i> (Schwaegr.) Schimp.	H				G
<i>Dichelyma falcatum</i> (Hedw.) Myr.		K		C	
<i>D. pallescens</i> BSG		K		C	
<i>Dichodontium pellucidum</i> (Hedw.) Schimp.		K	M	C	J
<i>Dicranella heteromalla</i> (Hedw.) Schimp.	H	K			D G
<i>D. schreberiana</i> (Hedw.) Schimp.	H	+			
<i>D. subulata</i> (Hedw.) Schimp.	+	+			
* <i>D. varia</i> (Hedw.) Schimp.	H	K			D
<i>Dicranoweisia crispula</i> (Hedw.) Lindb.		K	M		
* <i>Dicranum condensatum</i> Hedw.		K			
<i>D. flagellare</i> Hedw.	H	K		J	D G
<i>D. fuscescens</i> Turn.	H	+			G
<i>D. montanum</i> Hedw.	H	K	M	J	D G
* <i>D. ontariense</i> Peters.	H	K			D G
<i>D. polysetum</i> Sw.	H	K	M	J	D G
<i>D. scoparium</i> Hedw.	H	K	M	J	D G
<i>D. undulatum</i> Brid.		K			
* <i>D. viride</i> (Sull. & Lesq.) Lindb.	H	K		J	D
* <i>Didymodon rigidulus</i> Hedw.		K			
<i>Diphyscium foliosum</i> (Hedw.) Mohr	H	K			D G
<i>Distichium capillaceum</i> (Hedw.) BSG		K	M	C	J D
* <i>D. inclinatum</i> (Hedw.) BSG		K			
* <i>Ditrichum flexicaule</i> (Schwaegr.) Hampe		K		C	
* <i>D. lineare</i> (Sw.) Lindb.	H				
* <i>D. pusillum</i> (Hedw.) Hampe	H	K			D
<i>Drepanocladus aduncus</i> (Hedw.) Warnst.	H	K			
* <i>D. fluitans</i> (Hedw.) Warnst.	H	K		C	
<i>D. uncinatus</i> (Hedw.) Warnst.	H	K	M	C	J D G
* <i>D. vernicosus</i> (Lindb.) Warnst.		K		C	
<i>Dryptodon patens</i> (Hedw.) Brid.		+			
<i>Encalypta ciliata</i> Hedw.		K	M	J	
<i>E. procera</i> Bruch.		K	M	J	
* <i>E. raptocarpa</i> Schwaegr.		K			
<i>Entodon cladorrhizans</i> (Hedw.) C. M.		+			
<i>Eurhynchium pulchellum</i> (Hedw.) Jenn.	H	K	M	J	D G
<i>E. riparioides</i> (Hedw.) Rich.	H	K	M	J	
* <i>Fissidens adianthoides</i> Hedw.	H	K		C	J
<i>F. bryoides</i> Hedw.	H	K	M	J	G
* <i>F. cristatus</i> Wils. ex Mitt.	H	K	M	J	D
<i>F. fontanus</i> (B.-Pyl.) Steud.	H				
<i>F. grandifrons</i> Brid.		K		J	
<i>F. osmundioides</i> Hedw.	H	K	M	C	J D G
<i>Fontinalis antipyretica</i> var. <i>gigantea</i> (Sull.) Sull.	H	K			
<i>F. duriaei</i> Schimp.	H	+			
<i>F. flaccida</i> Ren. & Card.	H				
<i>F. hypnoides</i> C. J. Hartm.	H	K	M		

<i>F. neomexicana</i> Sull. & Lesq.	H								
<i>F. novae-angliae</i> Sull.	H K	M							
<i>Funaria hygrometrica</i> Hedw.	H K			J	D				
<i>Grimmia affinis</i> Hoppe & Hornsch.	K				D				
<i>G. agassizii</i> (Sull. & Lesq.) Jaeg. & Sauerb.	+								
<i>G. alpicola</i> Hedw.	H K	M	C	J		G			
<i>G. alpicola</i> var. <i>dupretii</i> (Ther.) Crum	+								
* <i>G. alpicola</i> var. <i>rivularis</i> (Brid.) Wahl.	K	M	C	J					
<i>G. apocarpa</i> Hedw.	+ K		C	J	D				
<i>G. hartmanii</i> var. <i>anomala</i> (Hampe) Monk.	K								
<i>G. hermannii</i> Crum	+ +	M							
* <i>G. unicolor</i> Hook.	H K								
<i>Gymnostomum aeruginosum</i> Sm.	K	M		J					
* <i>G. recurvirostrum</i> Hedw.	K								
<i>Gyroweisia tenuis</i> (Hedw.) Schimp.	+								
<i>Haplocladium virginianum</i> (Brid.) Broth.	?								
<i>Hedwigia ciliata</i> (Hedw.) P.-B.	H K		C		D				
* <i>Herzogiella striatella</i> (Brid.) Iwats.	H					G			
* <i>H. turfacea</i> (Lindb.) Iwats.	K								
<i>Heterocladium dimorphum</i> (Brid.) BSG	H K	M	C	J	D	G			
<i>Homalia trichomanoides</i> (Hedw.) BSG	H K	M		J	D				
* <i>Homomallium adnatum</i> (Hedw.) Broth.	K				D				
<i>Hygrohypnum luridum</i> (Hedw.) Jenn.	H K	M	C	J					
<i>H. molle</i> (Hedw.) Loeske	K			J					
<i>H. ochraceum</i> (Turn.) Loeske	H K					G			
<i>Hylocomium pyrenaicum</i> (Spruce) Lindb.	K	M			D				
<i>H. splendens</i> (Hedw.) BSG	H K	M		J	D	G			
* <i>Hypnum cupressiforme</i> Hedw.	H K				D				
* <i>H. curvifolium</i> Hedw.	K								
<i>H. fertile</i> Sendtn.	?								
<i>H. imponens</i> Hedw.	K	M							
<i>H. lindbergii</i> Mitt.	H K	M			D	G			
<i>H. pallescens</i> (Hedw.) P.-B.	H K		C	J	D	G			
* <i>Isopterygium distichaceum</i> (Mitt.) Jaeg. & Sauerb.	K				D				
* <i>I. elegans</i> (Brid.) Lindb.	H					G			
* <i>I. pulchellum</i> (Hedw.) Jaeg. & Sauerb.	H K				D	G			
<i>Leptobryum pyriforme</i> (Hedw.) Schimp.	H K					G			
<i>Leskea gracilescens</i> Hedw.	K								
<i>Leskeella nervosa</i> (Brid.) Loeske	H K			J	D				
* <i>Leucobryum glaucum</i> (Hedw.) Angstr.	H K				D	G			
<i>Leucodon brachypus</i> var. <i>andrewsianus</i> Crum & Anderson	H K				D				
* <i>Lindbergia brachyptera</i> (Mitt.) Kindb.	H K				D				
<i>Meesia uliginosa</i> Hedw.	K								
<i>Mnium affine</i> var. <i>ciliare</i> C. M.	H K								
<i>M. cinclidioides</i> Hueb.	H								
<i>M. cuspidatum</i> Hedw.	H K			J	D	G			
<i>M. drummondii</i> Bruch & Schimp.	H +								
* <i>M. marginatum</i> (With.) Brid.	H K			J		G			
* <i>M. medium</i> BSG	H K								
* <i>M. punctatum</i> Hedw.	H K	M	C	J	D	G			
<i>M. punctatum</i> var. <i>elatum</i> Schimp.	H								
<i>M. spinulosum</i> BSG	H K			J	D				
<i>M. stellare</i> Hedw.	+ K								
<i>M. thomsonii</i> Schimp.	K	M	C	J					
<i>Myurella julacea</i> (Schwaegr.) BSG	K		C						
<i>M. sibirica</i> (C. M.) Reim.	K	M		J	D				
<i>Neckera pennata</i> Hedw.	H K	M		J	D				

<i>Oncophorus virens</i> (Hedw.) Brid.	K	C		
<i>O. wahlenbergii</i> Brid.	H K		J	
<i>Orthotrichum alpestre</i> Hornsch.	K			D
<i>O. anomalum</i> Hedw.	+			
<i>O. obtusifolium</i> Brid.	H K		J	G
<i>O. pallens</i> Bruch	+			
<i>O. sordidum</i> Sull. & Lesq.	H K			D G
<i>O. speciosum</i> var. <i>elegans</i> (Schwaegr.) Warnst.	K		J	D
<i>O. strangulatum</i> P.-B.	K			D
<i>Paraleucobryum longifolium</i> (Hedw.) Loeske	H K		J	D G
<i>Philonotis fontana</i> (Hedw.) Brid.	H K		C	G
<i>Physcomitrium pyriforme</i> (Hedw.) De Not.	H			
<i>Plagiopus oederiana</i> (Brid.) Limpr.	K	M	J	D
<i>Plagiothecium cavifolium</i> (Brid.) Iwats.	H K			D G
<i>P. denticulatum</i> (Hedw.) BSG	H K			D G
<i>P. laetum</i> BSG	H K		J	D G
** <i>P. latebricola</i> BSG	K			D
* <i>Platydictya jungermannioides</i> (Brid.) Crum	K	M		
<i>P. subtile</i> (Hedw.) Crum	+	K		J
<i>Platygyrium repens</i> (Brid.) BSG	H K			D G
<i>Pleurozium schreberi</i> (Brid.) Mitt.	H K	M	C	J D G
<i>Pogonatum alpinum</i> (Hedw.) Rohl.	H K		C	J D G
* <i>Pohlia cruda</i> (Hedw.) Lindb.	H K	M	C	J D G
* <i>P. lescuriana</i> (Sull.) Grout	H			
<i>P. nutans</i> (Hedw.) Lindb.	H K		J	D G
<i>P. proligera</i> (Kindb.) Lindb.	H K			G
* <i>P. wahlenbergii</i> (Web. & Mohr) Andr.	H K		J	D G
<i>Polytrichum commune</i> Hedw.	H K			
* <i>P. formosum</i> Hedw.	H			
<i>P. juniperinum</i> Hedw.	H K		C	J D G
* <i>P. juniperinum</i> var. <i>affine</i> (Funck) Brid.	H K			
<i>P. longisetum</i> Brid.	+	K		
* <i>P. pallidisetum</i> Funck	H			
<i>P. piliferum</i> Hedw.	H K			D G
<i>Pseudoleskea patens</i> (Lindb.) Kindb.	K			
* <i>P. radicata</i> (Mitt.) Macoun & Kindb.	K			D
<i>Pseudoleskeella tectorum</i> (A. Br.) Kindb.	K			D
** <i>Pterigynandrum filiforme</i> Hedw.	K			D
<i>Ptilium crista-castrensis</i> (Hedw.) De Not.	H K	M	J	G
* <i>Pylaisiella polyantha</i> (Hedw.) Grout	H K		J	D G
<i>P. selwynii</i> (Kindb.) Crum, Steere, & Anderson	H K		J	D
<i>Racomitrium aciculare</i> (Hedw.) Brid.	H K			
<i>R. canescens</i> (Hedw.) Brid.	H K			
* <i>R. fasciculare</i> (Hedw.) Brid.	K			
<i>R. heterostichum</i> (Hedw.) Brid.	H +			+ G
* <i>Rhabdoweisia crispata</i> (With.) Lindb.	H K		J	G
<i>Rhodobryum roseum</i> (Hedw.) Limpr.	H K			D
<i>Rhynchostegium serrulatum</i> (Hedw.) Jaeg. & Sauerb.	K			
<i>Rhytidiadelphus squarrosus</i> (Hedw.) Warnst.	K			
<i>R. triquetrus</i> (Hedw.) Warnst.	H K	M	J	D G
<i>Rhytidium rugosum</i> (Hedw.) Kindb.	K			D
<i>Saelania glaucescens</i> (Hedw.) Broth.	K		C	D
<i>Seligeria donniana</i> (Sm.) C. M.	?			
* <i>Sphagnum capillifolium</i> (Ehrh.) Hedw.	H			G
* <i>S. capillifolium</i> var. <i>tenellum</i> (Schimp.) Crum	+			
* <i>S. compactum</i> DC	K			
<i>S. cuspidatum</i> Ehrh.	+	K		

* <i>S. fimbriatum</i> Wils.	H				
* <i>S. fuscum</i> (Schimp.) Klinggr.	K				
* <i>S. girgensohnii</i> Russ.	H				G
* <i>S. magellanicum</i> Brid.	H K				
<i>S. majus</i> (Russ.) C. Jens.	+ K				
<i>S. papillosum</i> Lindb.	K				
* <i>S. pulchrum</i> (Lindb.) Warnst.	K				
* <i>S. recurvum</i> var. <i>brevifolium</i> (Lindb.) Warnst.	+				
* <i>S. recurvum</i> var. <i>tenue</i> Klinggr.	K				
* <i>S. russowii</i> Warnst.	H K				G
<i>S. squarrosus</i> Crome	H				G
<i>S. subsecundum</i> var. <i>contortum</i> (Schultz) Hueb.	+				
<i>Tetraphis pellucida</i> Hedw.	H K		J	D	G
<i>Tetraplodon mnioides</i> (Hedw.) BSG	+				
<i>Thuidium abietinum</i> (Hedw.) BSG	K	M	C	J	D
<i>T. delicatulum</i> (Hedw.) BSG	H K	M		J	D G
<i>T. recognitum</i> (Hedw.) Lindb.	H K			J	
<i>Timmia austriaca</i> Hedw.	K	M			
* <i>Tomenthypnum nitens</i> (Hedw.) Loeske	K				D
<i>Tortella fragilis</i> (Hook. & Wils.) Limpr.	K		C		
<i>T. humilis</i> (Hedw.) Jenn.	K				
<i>T. tortuosa</i> (Hedw.) Limpr.	H K	M	C	J	D
<i>Tortula mucronifolia</i> Schwaegr.	K				
<i>T. ruralis</i> (Hedw.) Crome	K				D
<i>Trematodon ambiguus</i> (Hedw.) Hornsch.	H K				D
<i>Trichodon cylindricus</i> (Hedw.) Schimp.	H +				
<i>Trichostomum tenuirostre</i> (Hook. & Tayl.) Lindb.	H +				
<i>Ulota coarctata</i> (P.Beauv.) Hamm.	?				
<i>U. crispa</i> (Hedw.) Brid.	H K				D
* <i>U. hutchinsiae</i> (Sm.) Hamm.	K				D

Excluded moss taxa include *Atrichum angustatum* (Brid.) BSG, *Barbula cylindrica* (Tayl.) Schimp., *Brachythecium calcareum* Kindb., *Climacium americanum* Brid., *Dicranum fulvum* Hook., *D. muehlenbeckii* BSG, *Haplocladium microphyllum* (Hedw.) Broth., *Hygrohypnum eugyrium* (BSG) Loeske, *Isopterygiopsis muelleriana* (Schimp.) Iwats., *Mielichhoferia mielichhoferi* (Funck) Loeske.

Liverworts

<i>Anastrophyllum helleranum</i> (Nees) Schust.	+				
<i>A. michauxii</i> (Web.) Buch	+				
<i>A. minutum</i> (Schreb.) Schust.	H +				G
<i>Asterella gracilis</i> (Web.) Underw.	+				
<i>Barbilophozia attenuata</i> (Mart.) Loeske	K			J D	
<i>B. barbata</i> (Schmid.) Loeske	H K		M C J D G		
<i>B. hatcheri</i> (Evans) Loeske	K		C J		
<i>B. kunzeana</i> (Hueb.) Gams	+				
<i>B. lycopodioides</i> (Wallr.) Loeske	+				
<i>B. quadriloba</i> (Lindb.) Loeske	+				
<i>Bazzania trilobata</i> (L.) S. Gray	H K			J G	
* <i>Blasia pusilla</i> L.	H K			D G	
<i>Blepharostoma trichophyllum</i> (L.) Dum.	H K		C J D G		
** <i>Calypogeja fissa</i> (L.) Raddi	H				G
<i>C. integristipula</i> Steph.	+				
* <i>C. muelleriana</i> (Schiffn.) K. Muell.	H				G
<i>C. neesiana</i> (Mass. & Carest.) K. Muell.	H				
* <i>C. trichomanis</i> (L.) Corda	H				G
<i>Cephalozia catenulata</i> (Hueb.) Lindb.	+				
* <i>C. connivens</i> (Dicks.) Lindb.	K				
<i>C. lunulifolia</i> (Dum.) Dum.	K			J	
* <i>C. macounii</i> (Aust.) Aust.	H				G
<i>C. pleniceps</i> (Aust.) Lindb.	+				
<i>Cephaloziella arctica</i> Bryhn & Douin	+				
<i>C. divaricata</i> (Sm.) Schiffn.	+				
<i>C. elachista</i> (Jack) Schiffn.	+				
<i>C. hampeana</i> (Nees) Schiffn.	K			D	
<i>Chiloscyphus polyanthos</i> (L.) Corda	K				
* <i>Conocephalum conicum</i> (L.) Lindb.	H K			J G	
<i>Cryptocolea imbricata</i> Schust.	+				
<i>Frullania bolanderi</i> Aust.	H K			J D	
<i>F. brittoniae</i> Evans	+				
<i>F. eboracensis</i> Gott.	H K			J D G	
<i>F. oakesiana</i> Aust.	+				
<i>F. selwyniana</i> Pears.	+				
<i>F. tamarisci</i> (L.) Dum.	+				
* <i>Geocalyx graveolens</i> (Schrad.) Nees	H K				G
<i>Jamesoniella autumnalis</i> (DC) Steph.	K		M J D		
<i>Jungermannia hyalina</i> Lyell	+				
<i>J. leiantha</i> Grolle	H +				G
<i>J. polaris</i> Lindb.	+				
<i>J. pumila</i> With.	+ K			D	
<i>J. sphaerocarpa</i> Hook.	+				
<i>Kurzia setacea</i> (Web.) Grolle	K				
<i>Lejeunea cavifolia</i> (Ehrh.) Lindb.	K		M J D		
<i>Lepidozia reptans</i> (L.) Dum.	H K			J G	
<i>Lophocolea heterophylla</i> (Schrad.) Dum.	H K			J D G	
<i>L. minor</i> Nees	K			D	
<i>Lophozia alpestris</i> (Schleich.) Evans	+				
<i>L. ascendens</i> (Warnst.) Schust.	+				
<i>L. bicrenata</i> (Schmid.) Dum.	+				
<i>L. excisa</i> (Dicks.) Dum.	+				
<i>L. gillmanii</i> (Aust.) Schust.	+				

<i>L. guttulata</i> (Lindb. & Arn.) Evans	+				
<i>L. heterocolpa</i> (Thed.) M. A. Howe	K			D	
<i>L. incisa</i> (Schr.) Dum.	K			J	
<i>L. laxa</i> (Lindb.) Grolle	+				
<i>L. longidens</i> (Lindb.) Macoun	+				
<i>L. obtusa</i> (Lindb.) Evans	+				
<i>L. rutheana</i> (Limpr.) M. A. Howe	+				
<i>L. ventricosa</i> (Dicks.) Dum.	H +				G
<i>Marchantia polymorpha</i> L.	H +				
<i>Metzgeria furcata</i> (L.) Dum.	K			D	
<i>Mylia anomala</i> (Hook.) S. Gray	H K				G
<i>Nowellia curvifolia</i> (Dicks.) Mitt.	H K			J	G
<i>Odontoschisma denudatum</i> (Nees) Dum.	+				
<i>Pellia endiviiifolia</i> (Dicks.) Dum.	H +				
* <i>P. epiphylla</i> (L.) Corda	H K			D	G
<i>P. neesiana</i> (Gott.) Limpr.	+				
<i>Plagiochila porelloides</i> (Torrey) Lindenb.	H K	M		J	D G
* <i>Porella platyphylla</i> (L.) Pfeiff.	H K			J	D
* <i>P. platyphylloidea</i> (Schwein.) Lindb.	H K			J	D
* <i>Preissia quadrata</i> (Scop.) Nees	H K	M			G
<i>Ptilidium ciliare</i> (L.) Hampe	K			C	D
<i>P. pulcherrimum</i> (G. Web.) Vainio	H K	M		J	D G
<i>Radula complanata</i> (L.) Dum.	H K	M	C	J	D
* <i>Riccardia multifida</i> (L.) S. Gray	K				D
* <i>Riccia fluitans</i> L.	H				
* <i>Scapania curta</i> (Mart.) Dum.	K			C	
<i>S. cuspiduligera</i> (Nees) K. Muell.	K			C	
<i>S. gymnostomophila</i> Kaal.	K				D
<i>S. irrigua</i> (Nees) Gott. <i>et al.</i>	H K				D
<i>S. lingulata</i> Buch	K				
<i>S. mucronata</i> Buch	K			C	
<i>S. nemorosa</i> (L.) Dum.	H +				G
* <i>S. undulata</i> (L.) Dum.	H K				
* <i>Trichocolea tomentella</i> (Ehrh.) Dum.	H				
<i>Tritomaria exsecta</i> (Schr.) Loeske	H +				G
<i>T. exsectiformis</i> (Breidl.) Loeske	K			J	
<i>T. quinquedentata</i> (Huds.) Buch	K	M			
<i>T. scitula</i> (Tayl.) Joerg.	K			C	

* New for Keweenaw Peninsula

** New for Upper Peninsula

H Houghton Co. specimen seen

K Keweenaw Co. specimen seen

+ Literature report, not seen; column indicates Houghton or Keweenaw County

? Doubtful record; column indicates Houghton or Keweenaw County

M Manganese Falls

C Cat Harbor

J Jacobs Falls

D Cliff Drive

G Gooseneck Creek

245 AN OLD-GROWTH WHITE PINE STAND IN THE HURON MOUNTAINS, UPPER MICHIGAN

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The Huron Mountain Club wilderness area consists of 4,000 hectares (16 sq. mi) of mountain lakes and virgin forests. In 1962, in cooperation with the Michigan Natural Areas Council, the club dedicated the area as a *Nature Research Area* so that it could be preserved for ecological studies. The vegetation and topography of the area were described by Wells and Thompson (1976). Recently, I was surprised to discover an old-growth white pine stand located south of Mummy Mountain approximately 150 m to the south of Fisher Creek Trail (SE¼ NW¼ Sec. 32, T 52 N, R 28 W, Marquette County). Stands of this type are very rare today because of the widespread lumbering in the Upper Peninsula. Bourdo (1961) reported that such "stands have virtually disappeared." Because of the scarcity of these tracts and the fact that very few have been described, a study to describe the stand was undertaken.

The study tract is located on flat ground covering an area of approximately 2.56 ha (6.33 acres) and 125 × 210 m in dimensions. Eight 40 × 80 m contiguous plots were laid out, completely covering the area in which the white pines were concentrated. Following the procedures used in earlier studies (Thompson 1963, 1981), all trees with diameters exceeding 6.4 cm (20 cm circumference) were measured at breast height (1.4m), although there were no trees in the diameter range 6.4–45 cm. In addition the height and crown diameter of six white pines, one sugar maple, and one white spruce were measured. One of the larger pines (60 cm diameter) was cored using an increment borer. The diameter and basal area of each tree were calculated from the circumference measurement, and the relative dominance for each species was calculated from the total basal area of the species. The scientific names of the trees are shown in Table 1.

RESULTS AND DISCUSSION

The data (Table 1 and 2) show the overwhelming dominance of white pine. Of a total of 40 trees in the tract, 34 (85%) are white pine, and the remaining six are represented by four different species. Most of the pines are large; 24 have diameters exceeding 78 cm (over 2.5 ft) and of these, 10 possess diameters greater than 92 cm (over 3 ft). The basal area of white pine is 19.7 m² or 90% of the total basal area (21.8 m²) of all species. Because of

TABLE 1. Composition of the Fisher Creek white pine stand, Huron Mountains, Upper Michigan based on complete coverage by eight 40 × 80 m plots.

Species	Diameter Range (cm)	No. Trees	Basal Area (m ²)	Relative Dominance (%)
White Pine	6–45	0	0.00	
(<i>Pinus strobus</i>)	45–60	4	0.92	
	60–70	3	0.92	
	70–80	6	2.66	
	80–90	10	5.58	
	90–100	7	4.96	
	100–130	3	3.06	
	142	1	1.59	
White Pine (total)		34	19.69	90.3
Sugar Maple	61; 69	2	0.66	3.1
(<i>Acer saccharum</i>)				
White Spruce	52; 73	2	0.64	3.0
(<i>Picea glauca</i>)				
Hemlock	85	1	0.56	2.6
(<i>Tsuga canadensis</i>)				
Largetooth Aspen	52	1	0.22	1.0
(<i>Populus grandidentata</i>)				
All species (total)		40	21.77	100.0

TABLE 2. Composition of eight 40 × 80 m plots in the Fisher Creek white pine stand, Huron Mountains, Upper Michigan.

Plot No.	Species	No. Trees	Diameter (cm)		Basal (m ²)	Basal Area All Species (m ² /ha)
			Mean	Range		
1	White Pine	8	81.9	59.9–130.3	4.48	16.9
	Sugar Maple	1	68.8		0.37	
	Hemlock	1	84.6		0.56	
2	White Pine	4	81.5	48.3–110.7	2.23	7.0
3	White Pine	3	107.3	84.1–142.2	2.86	8.9
4	White Pine	7	80.4	57.4–99.3	3.65	11.4
5	White Pine	4	74.1	61.5–84.6	1.75	9.1
	Sugar Maple	1	60.7		0.29	
	White Spruce	2	62.7	52.6–72.9	0.64	
	Largetooth Aspen	1	52.6		0.22	
6	White Pine	2	96.1	94.5–97.8	1.45	4.5
7	White Pine	1	100.3		0.79	2.5
8	White Pine	5	78.0	50.0–93.0	2.48	7.8

their large size, the total number of trees per unit area is relatively small, amounting to 15.6 per hectare (6.2 per acre) with 13.3 white pine per hectare (5.3 per acre).

The dimensions of the trees for which circumference, height, and crown spread were measured are shown in Table 3. The trees are tall; the average height of the pines is 46.5 m, and of the six measured, five are 46 m (150 ft) or taller. The sixth pine, a sugar maple, and a white spruce exceeded 38 m (125 ft). The largest and tallest tree is a white pine with a diameter of 142 cm

TABLE 3. Individual tree measurements, Fisher Creek White Pine Stand, Huron Mountains, Upper Michigan.

Species	Diameter (cm)	Circum. (cm)	Height (m)	Crown Spread (m)
White Pine	59.8	188	46	19
White Pine	129.2	406	46	19
White Pine	95.5	300	39	19
White Pine	142.3	447	54	18
White Pine	99.3	312	48	16
White Pine	100.3	315	46	17
Average	104.4	328	46.5	18
Sugar Maple	68.8	216	40	24
White Spruce	72.9	229	40	10

(56 in) and a height of 54 m (176 ft). The average crown spread is 18 m. The cored pine had an estimated age of 250 years.

An examination of the understory layer of shrubs and trees less than 6.4 cm in diameter revealed that sugar maple saplings, hundreds in number, far outnumbered all other species. No pine reproduction was observed. The coverage classes of the various species (Braun-Blanquet 1932) is given below:

Species	Coverage Class
Sugar Maple (<i>Acer saccharum</i>)	4
Birch (<i>Betula</i> spp.)	2
Striped Maple (<i>Acer pensylvanicum</i>)	1
Canada Honeysuckle (<i>Lonicera canadensis</i>)	+
Northern White-Cedar (<i>Thuja occidentalis</i>)	+
White Spruce (<i>Picea glauca</i>)	+
Balsam Fir (<i>Abies balsamea</i>)	+
Largetooth Aspen (<i>Populus grandidentata</i>)	+

The groundcover is composed of a multitude of sugar maple seedlings and a few seedlings of striped maple. The principal herbaceous species are starflower (*Trientalis borealis*), Canada Mayflower (*Maianthemum canadense*), wild sarsaparilla (*Aralia nudicaulis*), twisted stalk (*Streptopus rosea*), and wood fern (*Dryopteris* spp.). Other species include bedstraw (*Galium* spp.), yellow violet (*Viola eriocarpa*), roundleaf hepatica (*Hepatica americana*), partridge berry (*Mitchella repens*), Indian pipe (*Monotropa uniflora*), shining clubmoss (*Lycopodium lucidulum*), and bracken fern (*Pteridium aquilinum*). Several species are confined to the moister, southern portion of the study tract: goldthread (*Coptis trifolia*), bunchberry (*Cornus canadensis*), bluebead lily (*Clintonia borealis*), alpine enchanter's nightshade (*Circaea alpina*), rattlesnake plantain (*Goodyera tessellata*), and northern oak fern (*Gymnocarpium dryopteris*).

The large number of sugar maples in the understory and the groundcover layer and the absence of pine reproduction indicate a trend to a hardwood stand composition in the future.

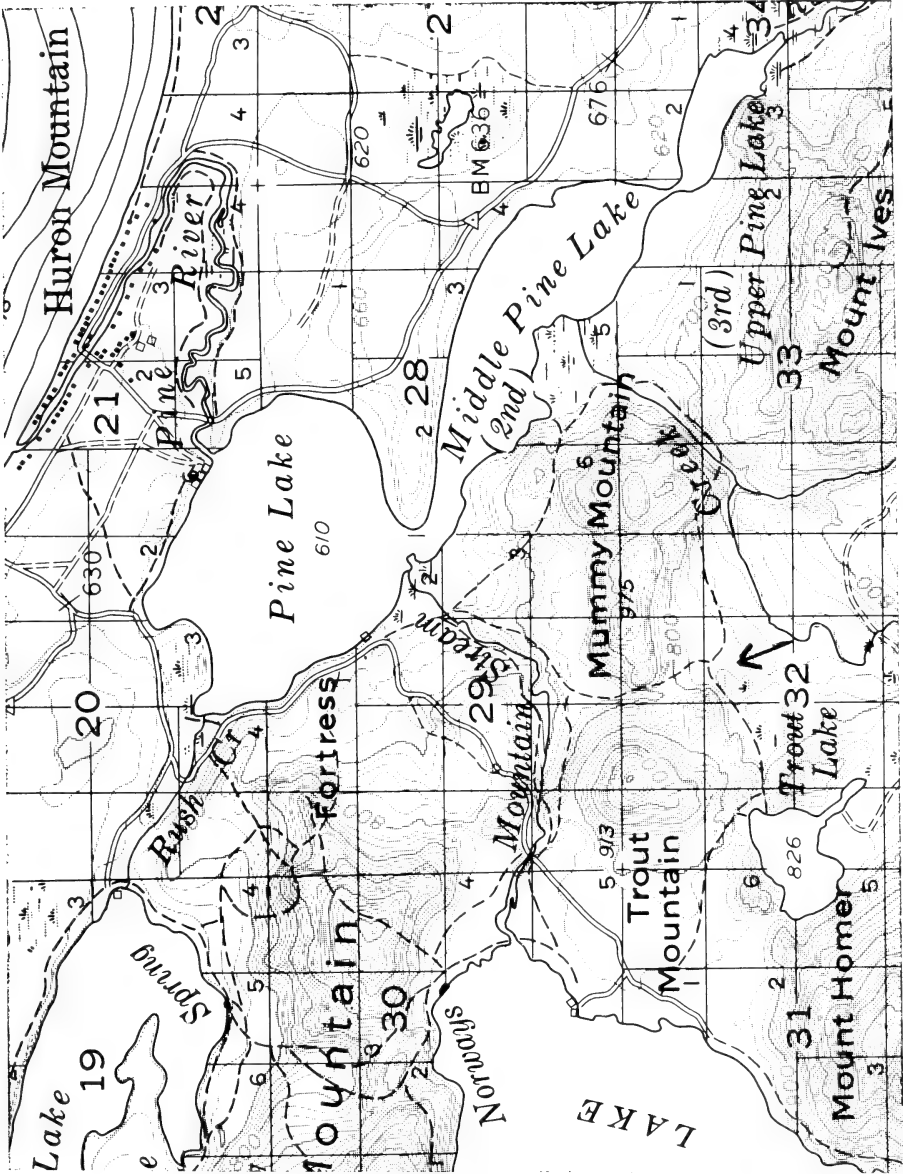


Fig. 1. Location of tract (SE ¼ NW ¼ Sec. 32, T 52 N, R 28 W) is indicated by the arrow next to the number "32" in the lower center of the map.

The Huron Mountain Club is to be commended on their decision to preserve this extensive virgin wilderness area. Thereby, unusual communities, such as this white pine forest, will be protected for further studies.

ACKNOWLEDGMENT

I wish to acknowledge the support of the Huron Mountain Wildlife Foundation for this project. I thank Dr. Burton V. Barnes for his assistance in the presentation of the data.

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NOTICE: TENTH NORTH AMERICAN PRAIRIE CONFERENCE

The Tenth North American Prairie Conference, sponsored by the Native Prairies Association of Texas in conjunction with the Texas Department of Agriculture, Texas General Land Office as well as Texas Woman's University, North Texas State University and other participating universities, will be held on the campus of Texas Woman's University in Denton, Texas from June 22 through June 26, 1985.

The theme for the conference is: "North American Prairie: the Roots of Our Culture, the Foundation of Our Economy." The conference is planned for Professionals, Researchers, and Educators to exchange data on native prairie ecosystems, past, present, and future.

Proposals are encouraged—for papers, workshops, etc. Deadline for proposals/abstracts is December 15, 1985. For more information contact: Program Committee, Native Prairies Association of Texas, TWU, P. O. Box 22675, Denton, Texas 76204.

THE USE OF VEGETATIVE PROPAGULES FOR STERILE CULTURES OF AQUATIC MACROPHYTES

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Sterile laboratory cultures of aquatic macrophytes have been useful for the study of nutrient requirements, nutrient uptake, photosynthesis, respiration, and other physiological processes. Other potential uses of sterile or axenic macrophyte cultures are to study macrophyte pathology, life history, and propagation. The use of macrophyte cultures in the laboratory has a relatively short history. Bourn (1932) performed several laboratory experiments with *Potamogeton pectinatus* grown from both shoot fragments and tubers. However, he did not use sterile cultures. Sterile cultures grown from shoot fragments were attempted by Wilson (1972). In this technique, shoot segments are washed with sodium hypochlorite solutions until the leaves are bleached. More commonly, axenic macrophyte cultures have been grown from seeds that have been sterilized and then germinated in sterile culture media (Wetzel & MacGregor 1968; Forsberg 1965, 1966; Gerloff & Krombholz 1966; Stanley 1970). In general, the sterilizing agent used is sodium hypochlorite. Gerloff and Krombholz (1966) used a 1.05% sodium hypochlorite solution (0.2 strength Chlorox), immersing seeds for 15 minutes to produce algal-free cultures of several lake species. Stanley (1970) grew algal-free cultures of *Myriophyllum spicatum* from seeds sterilized in 0.625% sodium hypochlorite plus detergent.

Culturing aquatic vascular plants from seeds is difficult, and often impossible, for a given species of interest. Collecting seeds from the field may be time-consuming, due to the low density of seeds in many aquatic vascular plant species. Seeds are generally available only during a short period of time (mid-summer to fall). In addition, seeds that have been collected are often difficult to germinate. Seeds in axenic cultures may not germinate due to special germination requirements (Wetzel & MacGregor 1968; Forsberg 1965, 1966). Seeds may require scarification, stratification, chemical treatments, special light conditions, low oxygen tensions, or low redox potential. Even if some seeds do germinate, germination ratios are often low. Many aquatic vascular plants either do not flower or form sterile seeds, especially when growing in flowing waters (Sculthorpe 1967).

The formation of sterile cultures from shoot fragments is also difficult. To produce a sterile culture, plant fragments must be "bleached". Bleaching of leaves may kill the plant fragment (Wilson 1972). Storage of fragments

until the time of use is also difficult. Plant fragemtns must be collected during the growing season and used soon afterwards, or kept in aquaria.

Many aquatic macrophytes possess vegetative propagules. These propagules are often important to plant reproduction and dispersal (Kimbel 1982; Sastroudomo *et al.* 1979; Weber 1972). Vegetative propagules (such as tubers, turions, rhizomes, and hibernaculae) often have outer tissues that protect the meristematic tissues from damage. The presence of the "protective coat" makes vegetative propagules suitable for axenic culturing techniques: they can resist sterilization without a loss of viability. This paper discusses a technique used to grow algal-free cultures of *Potamogeton pectinatus* from tubers.

MATERIALS AND METHODS

Tubers of *Potamogeton pectinatus* (Sago Pondweed) were collected from Badfish Creek (Dane County, Wisconsin) in July and stored at 4° C until used. The tubers were sterilized in 5.25% sodium hypochlorite and rinsed in sterile distilled water. Treatments consisted of different lengths of time that the tubers were immersed in the sterilizing sodium hypochlorite solution. Treatments were 5, 15, 30, 60 and 120 minutes, with a control of tubers not immersed in sodium hypochlorite but rinsed with sterile distilled water. Twelve tubers were used in each treatment. Tubers were then transferred to a 3000 ml Florence flask with 2000 ml of sterile nutrient solution and incubated for 8 weeks in a controlled growth room. Environmental conditions in the room were $25 \pm 2^\circ \text{C}$ air temperature and $200 \mu\text{mol (photons) m}^{-2} \text{s}^{-1}$ light intensity (PhAR) on a 12 hr light/ 12 hr dark photoperiod. Air was bubbled through the flasks to prevent stagnation and provide a ready supply of free carbon dioxide.

The nutrient medium used was modified from Gerloff and Krombholz (1966; Gerloff 1973), and is presented in Table 1. The nutrient medium was sterilized in the 3000 ml Florence flask by autoclaving for 15 minutes at 20 psi.

At the end of the 8 week incubation period, the treatments were analyzed for contamination (by epiphyton, algae in the culture media, and fungi), percent germination of shoots and roots, and the growth of shoots and roots. Standard statistical comparisons were used not because treatments were not replicated (Hurlbert 1984).

RESULTS

Contamination by algae in the media and epiphytes were found in the control and 5 minute treatment, and by fungi in the 15 minute treatment (Table 2). Other cultures did not exhibit contamination. Percentage of

TABLE 1. Concentration of elements in nutrient solution (modified from Gerloff and Krombholz 1966; Gerloff 1973).

Element	ppm	Element	ppm
N	42	B	0.27
K	47	Mn	0.27
Ca	40	Zn	0.13
S	12.8	Cu	0.03
P	6.2	Mo	0.01
Mg	9.6	Fe (as Fe EDDHA)	0.56
Cl	1.77		

TABLE 2. Contamination of treatments by algae, epiphytes, and fungi.

Treatment (minutes)	Algae	Contamination Epiphytes	Fungi
0 (control)	X	X	
5	X	X	
15			
30			X
60			
120			

germination of both shoots and roots was highest in the 30 minute treatment (Figure 1, top). The growth of shoots and roots was also highest in the 30 minute treatment (Figure 1, bottom). Due to these three tests, the 30 minute treatment of tubers in sodium hypochlorite was selected as being the best combination of sterilization without decreasing tuber viability.

DISCUSSION

Decreased germination and growth of shoots and roots in the control, 5, and 15 minute treatments was probably due to competition or shading by contaminating algae or fungi. The presence of fungi in the control and 5 minute treatments may have been obscured by the density of algal growth. Algal growth appeared very rapidly in the control and 5 minute treatments. In the 60 and 120 minute treatments, reduced viability was probably due to the toxicity of sodium hypochlorite. Treated tubers take on a bleached appearance. In longer treatments sodium hypochlorite may cause injury or death to large amounts of storage or meristematic tissues.

Although the concentration of sodium hypochlorite used was much higher than in other studies, the optimal time of immersion in sodium hypochlorite was longer than that used for seeds (Gerloff & Kromholz 1966; Stanley 1970) or plant fragments (Wilson 1972). The total exposure to sodium hypochlorite required to sterilize the tubers was much higher than in the other reports. I speculate that this may be due to possible epiphyte colonization well into the tuber itself, whereas seed coats are more resistant and impenetrable. I did not vary the concentration of sodium hypochlorite used for immersion of tubers. To examine the most effective combination of immersion time and concentration, a full sequence of various sodium hypochlorite concentrations for a range of immersion times could be done.

I did not examine the experimental cultures for the presence of bacteria or organisms other than algae and fungi, so these cultures should be considered algal- and fungal-free, not axenic. Although most procedures do not require axenic conditions, some do. For those procedures requiring the absence of bacteria, axenic cultures should be possible using this technique.

The use of vegetative propagules, such as tubers, increases the number of species and environments from which plants may be taken for use in sterile

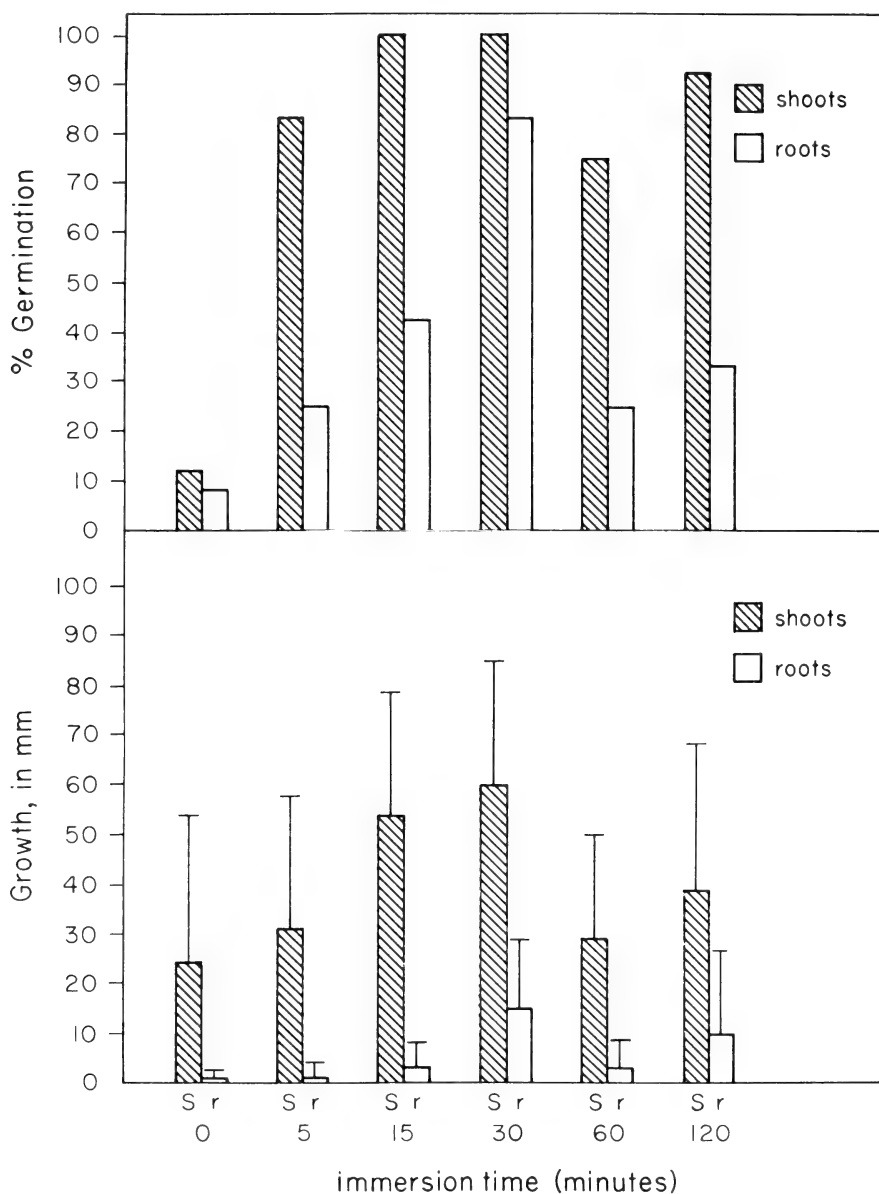


Fig. 1 Top: Percent germination of shoots and roots from tubers of *Potamogeton pectinatus* eight weeks after sterilization for various lengths of time (treatments) in 5.25% sodium hypochlorite, and incubated for eight weeks. Bottom: Growth of shoots and roots of *Potamogeton pectinatus* from tubers immersed in 5.25% sodium hypochlorite for various lengths of time (treatments), and incubated for eight weeks. Bar indicates +1 standard deviation.

cultures of aquatic macrophytes. Germination rates were very high in this study. In addition, the collection of tubers was easy, and germination requirements straightforward, as compared to seeds. The population from which the tubers were collected did not produce seeds, as is common with macrophytes that grow in streams. Tubers from this population were available at all times of the year except for the peak of the growing season (May—June).

In conclusion, the use of vegetative propagules to grow sterile or axenic cultures of aquatic macrophytes adds another technique in addition to those commonly used. Plant populations that do not form seeds or have seeds that do not germinate easily under lab conditions can be used in algal-free or axenic cultures.

SUMMARY

The tubers of *Potamogeton pectinatus* were used to grow an algal-free culture. Cultures were grown in sterilized Gerloff media. Tubers were sterilized by immersion in 5.25% sodium hypochlorite, with an optimal immersion time of 30 minutes. The use of vegetative propagules for growing algal-free cultures was compared to other methods, such as using seeds and shoot fragments.

ACKNOWLEDGMENTS

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Erratum

The publication date for the March 1985 issue (Vol. 24, no. 2) was incorrectly given in the May 1985 issue (Vol. 24, no. 3). The correct publication date for Vol 24, no. 3 is March 11, 1985.

The May issue (Vol. 24, no. 3) was mailed August 2, 1985.

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On the cover: *Cypripedium candidum*, small white lady's-slipper,
photographed in the West Chicago Prairie, Du Page County,
Illinois Forest Preserve District by Thomas A. Schutt on 15 May 1985.